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Notice to Subscribers

By action of the Association taken at the Annual Meeting in Richmond, Virginia, in December, 1946, the subscription price of the Journal for non-members of the Association was raised to $5.00 per year within the United States and to $5.50 for foreign addresses.

North Central States Branch

"Second annual meeting of the North Central States Branch of the A.A.E.E. to be held March 26 and 27, 1947, at Hotel Ft. Des Moines, Des Moines, Iowa. Copies of the 1946 Proceedings are available for $2.00 from J. W. Apple, 123 Natural Resources Building, Urbana, Illinois.

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Seasonal Occurrence of the Potato Psyllid in the North Platte Valley

R. L. WALLIS, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In the production of potatoes and tomatoes in several of the Western States considerable difficulty has been encountered from outbreaks of the potato psyllid, *Paratrioza cockerelli* (Sulc). These outbreaks vary from year to year with differing seasonal and environmental conditions. During years of high infestations plant growth is retarded, showing pronounced psyllid yellows and resulting in a reduction in yield and quality of potatoes and tomatoes. In years of light infestations no noticeable symptoms of plant injury may be present, and damage may be so small as to be difficult to determine. The causes of these seasonal variations have never been fully determined.

In 1939 the Bureau of Entomology and Plant Quarantine undertook an investigation of seasonal outbreaks of the potato psyllid in the North Platte Valley of Wyoming and Nebraska and the environmental factors affecting these outbreaks. In this paper data are presented on psyllid populations on cultivated crops and noneconomic hosts, which may be important breeding plants from 1940 to 1944, inclusive. No attempt is made to discuss the seasonal origin of this infestation except to show that it is apparently not within the Valley.

The principal theory as to its origin, and the one now being studied, is their possible long-distance movement from winter breeding areas in southern parts of Texas and Arizona. The following facts point to this as the probable overwintering place of the potato psyllid: (1) They have never been found during the winter in appreciable numbers in the local area. (2) That they have been caught in airplane traps as high as 5000 feet in the air indicates the probability of migration by air currents. (3) They have been captured in ground traps in conjunction with sugar beet leafhoppers that have migrated from these southern areas. (4) Reports show that infestations are generally heavier close to these winter breeding areas than in the areas farther north. (5) They apparently cannot withstand the high summer temperatures in these southern areas; therefore they disappear entirely from them during the hot weather and return again in the fall. (6) Cage studies show that they have been unable to withstand sub-zero temperatures on cedar trees in the northern areas.

PREVIOUS WORK.—In recent years several writers have mentioned the great variation from one season to another of damage due to psyllids, and some have discussed the probable causes. The true cause of psyllid yellows on potatoes and tomatoes was not discovered until 1927, when Richards and Blood (1933), working in Utah, attributed this disease to the feeding of the nymph of *Paratrioza cockerelli*. Therefore little mention is made in the literature of psyllid outbreaks before that time, since the insect was not recognized as a pest of these crops. However, Daniels (1937) states that the losses to potatoes in Colorado in 1911, which were attributed to American leaf roll, were undoubtedly caused largely by psyllids, and that the epidemic apparently continued into 1912. He further states that an early spring with moderately high temperature and low rainfall favors high psyllid infestations in the plains section by providing an abundance of suitable host plants. A serious outbreak of psyllids in 1931 in Colorado was attributed to a favorable spring which allowed the perennial host plant, groundcherry, to appear early in April. Daniels also reports considerable fluctuation in potato yields from 1931 to

1937, attributing this condition largely to a combination of drought and psyllid yellows, which appeared to occur simultaneously.

List (1939) reports serious damage to tomatoes in Colorado in 1898, 1904, 1906, 1911, 1912, 1915, and 1916, but the full significance of psyllid injury to tomatoes was not recognized during these early years. He reports damage to tomatoes almost every season in more recent years.

Hartman (1937) states that in Wyoming psyllid yellows was reported in the irrigated section around Torrington in 1931; it was reported from many irrigated sections of the State in 1932; in 1933 there were no complaints of damage except at Laramie; and in 1934 and 1935 psyllids were reported from every potato-producing section of the State. He further states that psyllid injury appears not to be affected by fluctuations in precipitation, but that there is a direct relationship between minimum winter temperatures and summer psyllid populations. Furthermore, high maximum temperatures occurring in late June and early July are more important in reducing psyllid damage than low winter temperatures.

List (1939) has shown by laboratory tests that the optimum range for psyllid development is rather narrow. The species thrives best at about 80° F.; oviposition, hatching, and survival are definitely reduced at a constant temperature of 90°; a temperature of 95° permits little increase in numbers; and 100° for 1 or 2 hours a day is lethal to eggs and nymphs. The source of the initial infestations of psyllids, which obviously have an effect on subsequent summer infestations, has never been fully investigated.

Daniels (1937) reports taking adult psyllids during the winter months on red cedars in protected locations. List (1939) suggests the possibility that the initial spring infestation comes from some distant breeding ground through migration, and Romney (1939) believes the source of the migrants which infest potato- and tomato-producing areas west of the mountains is southern Arizona, and of those which infest areas east of the mountains, is the lower Rio Grande drainage above Laredo, Tex.

METHODS.—Observation points were established at random throughout the North Platte Valley, and these points were visited and sampled at 5- to 7-day intervals. Ten observation points on each host plant were established. Population counts were made by the sweep-net method, and at each observation point from one to four samples of 100 sweeps each were taken, the number of samples depending on the area of host plants. The samples were taken at random to uniform manner. The sweeping was done by brushing the net briskly across the tops of the plants, allowing the plants to cover approximately half the net opening. Once across the tops of the plants was counted as one sweep.

HOST PLANTS.—The cultivated crops included in these tests were tomatoes and three plantings of potatoes. Tomatoes in this area are generally grown from plants set from about May 15 to June 15. This crop has a conparatively long growing season, which extends from the last killing frost in the spring until the first killing frost in the fall, and therefore has a longer period of exposure to psyllid attack than do potato crops.

For the purpose of this study the potato crop has been divided into three groups according to the dates of planting. That which is commercially known as the early crop is planted in April and constitutes less than 10 per cent of the total acreage planted to potatoes in this area. The early growth of this crop is made during the cool part of the season, and the plants reach their maximum growth in July, when summer temperatures normally reach a maximum. The crop is harvested early in August. The commercial late crop of potatoes is planted from about May 25 to July 1. In order to distinguish between the earliest and latest plantings of this crop, that part of the crop planted from May 25 to June 5 was designated a medium crop and that part planted from June 20 to 30 was designated a late crop. These crops are usually small in July, reach their maximum growth in September, and are harvested in late September and early October.

In 1941 it was discovered that potatoes growing in piles of cull tubers and matrimony-vine, *Lycium halimifolium* Mill., a cultivated ornamental, contained large numbers of psyllids early in the season,

and beginning with that year these hosts were included in the survey. Potatoes in cull piles are a result of sprouting and growth of tubers that have been discarded from commercial and farm-storage cellars during the spring. Growth starts in early April and continues at a rapid rate during the relatively cool weather and high rainfall of May and June. The rate of their growth is undoubtedly accelerated by the heat from decaying tubers at the bottom of the pile. Because of insufficient moisture these plants die by the second or third week of July. Matrimony-vine is a woody, perennial plant used as an ornamental around the older city and farm dwellings. This is one of the earliest of all the psyllid host plants. Leaves begin to appear about the first of April and remain

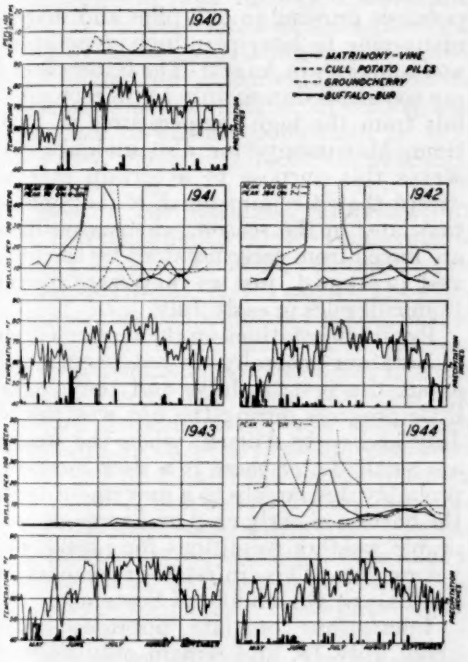

FIG. 1.—Populations of the adult potato psyllid on noneconomic hosts in the North Platte Valley, and weather data during corresponding period, 1940–1944. (Solid bars indicate rainfall.)

until freezing weather in the fall. It will withstand light frosts.

The important wild host plants of the potato psyllid are buffalo-bur, *Solanum rostratum* Dunal, and several species of groundcherry, *Physalis* spp. Buffalo-buris an herbaceous annual which reproduces by seed and is found abundantly in neglected fields, waste lands, and along roadsides. The seed is slow to germinate, and buffalo-bur is seldom found in this area before the first of June. The plants mature in late August and early Septem-

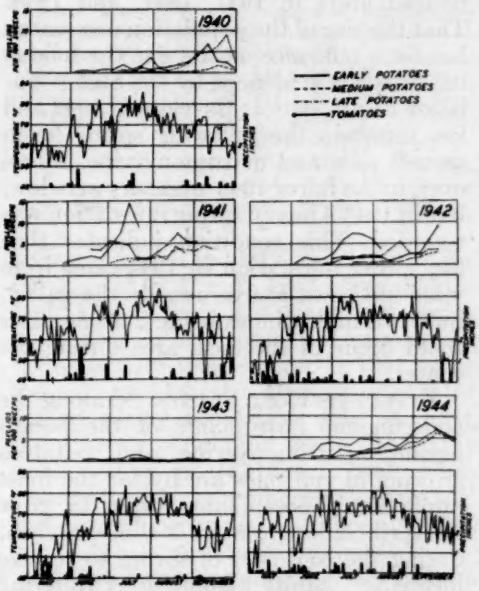

FIG. 2.—Populations of the adult potato psyllid on cultivated hosts in the North Platte Valley, and weather data during corresponding period, 1940–1944. (Solid bars indicate rainfall.)

ber. Wild groundcherry is an herbaceous perennial which reproduces and spreads mainly by rootstocks. Most species attain a height of 6 to 12 inches, but one species reaches 18 to 20 inches. They are generally found along roadsides, irrigation ditches, and in abandoned fields, and they thrive best in loose, sandy soil. Growth starts about the first of May and continues until killing frost in the fall.

RESULTS.—The results of the survey on noneconomic hosts for the five years 1940 to 1944 are shown in figure 1, and on cultivated hosts in figure 2. The temperature and precipitation records are for Scottsbluff, Nebr., which is near the center of the survey area.

VARIATIONS FROM ONE SEASON TO ANOTHER.—The population variations for all hosts from one year to another were not great, except during the 1943 season, when it was difficult to find psyllids at any time (Figs. 1 and 2). Though no data were

taken in 1940 on populations on piles of cull tubers and matrimony-vine, host plants that in other season have shown a heavy spring infestation, the indications are that the average infestation was only slightly less than normal. Large populations existed on noneconomic and cultivated hosts in 1941, 1942, and 1944. That the size of the population one season has little influence on the size the following season is evidenced by the high population on all hosts at the close of 1942 and low numbers the following spring, even on cull piles and matrimony-vine. Moreover, in the fall of 1943 numbers were low, but in 1944 a heavy spring infestation was recorded. This condition indicates that the spring infestation in 1944 came from some unknown source outside the valley, since it is highly improbable that increases could occur in the local area during the winter.

EFFECT OF HOST PLANTS.—Among the noneconomic host plants of the potato psyllid, matrimony-vine and potatoes growing in cull piles are by far the most important. These plants begin to grow in April. A long period is thus provided during the cool part of spring to receive incoming adults from overwintering sources, and a breeding place is available before cultivated crops become large enough to support infestations. Large spring populations build up on these plants, reaching a peak during the first few days in July, after which there is a marked decrease in numbers. Plants in cull piles die by late July or early August, and psyllids are forced to move to early potatoes, which serve to carry them over until late potatoes and tomatoes are large enough to support psyllid infestations. The population on matrimony-vine, although considerably reduced after the first of July, is maintained at a comparatively high level during the remainder of the season, with some build-up during the cool weather of the fall.

Wild groundcherry, which starts growth about May 1, does not become large enough to attract adults until after May, and then only in small numbers. The peak of spring infestations, which occurs about July 1, is small; therefore, this host has little importance in breeding psyllids which may move to cultivated crops. The populations found in the fall are similar to those found on cultivated crops.

Buffalo-bur does not receive any of the initial infestation moving from overwintering sources, for it is difficult to find psyllids on this host until after July 1. However, the fall build-up and the cessation of its growth about September 1 force a movement to other hosts, and this host is important only for the numbers it supplies to cultivated crops in the fall.

The early potato is the first cultivated crop of the season, and psyllid infestations start on this crop soon after June 1. Numbers increase until the latter part of July, when they reach a peak. Then they gradually decrease and are forced to later plantings when the crop is harvested in early August. This crop, which reaches its maximum growth in July when temperatures are high, serves as a means of carrying over some of the large numbers from potatoes growing in cull piles and matrimony-vine to later plantings of potatoes and tomatoes in August. The latter plants are too small during July to protect psyllids from the high temperatures at that time. Matrimony-vine also undoubtedly serves this purpose to a certain extent, except that it retains much of its population later in the season, whereas psyllids are forced from early potatoes by the harvest in August, just as they were forced from cull piles in early July.

Psyllid infestations on the medium crop of potatoes generally do not begin until about the first of July, and they make little progress during the hot weather of July and early August, when the plants are small. Later there is a slow increase, probably due largely to a movement from the harvested early crop and to more favorable weather conditions for psyllid development. This infestation reaches a peak about the middle of September.

Infestations on late potatoes begin about July 15, and remain only slightly smaller than those on medium potatoes for the remainder of the season. In 1940, however, for some unknown reason a fall peak failed to develop on this crop. As on the medium crop, psyllid numbers on late potatoes are increased in the fall by a movement of adults from the early crop. On tomatoes populations are slightly higher than on the medium and late plantings of potatoes. In 1941, when the crop developed somewhat earlier than usual, they appeared to include adults

from overwintering sources, and reached a peak in early July. The influence of temperature is shown this season by the reduction in numbers the latter part of July when maximum temperatures prevailed. In other seasons there is little change in numbers during the hot weather, but a noticeable increase in late August and September.

EFFECT OF WINTER TEMPERATURES ON POPULATIONS.—Table 1 shows the average populations of psyllids on all hosts in relation to temperature and precipitation for the five years of these investigations.

These data show that there is no apparent relationship between either winter temperature or precipitation and psyllid populations the following summer. The lowest mean temperature and the highest population were recorded in 1942, and the highest mean temperature and the lowest population in 1943. In 1941, however, the next to highest mean temperature and next to highest population were recorded. The highest precipitation in 1942 was associated with the highest population, but the next to highest population in 1941 followed the lowest recorded precipitation.

EFFECT OF SPRING TEMPERATURE ON INITIAL POPULATION.—Temperatures during May have an effect on the number of psyllids found (Figs. 1 and 2). The average monthly temperatures for May in 1941 and 1944 were 60.9° and 59.2° F., and the average populations on all hosts in these months were 15.3 and 14.8 per 100 sweeps, respectively. The average temperatures for May in 1942 and 1943 were 54.6° and 53.7°, and the population were 5.7 and 0.3, respectively. This indicates that low May temperatures tend to retard the movement of psyllids into the valley. The greatest increases occurred during June when temperatures were between 60° and 70° F.

EFFECT OF SUMMER TEMPERATURES ON POPULATIONS.—July temperatures, which are normally the highest for the summer, as well as the maximum spring populations, influence the size of populations for the remainder of the summer. The spring populations given in table 2 are averages of the peak populations on matrimony-vine and cull piles, the principal spring hosts, which occur about the first of July, and the summer populations are averages on all hosts after the spring peak. The July maximum temperature of 92.4° F. in 1943 prevented the building up from the very low spring population of any significant number for the remainder of the season. In 1942, when the next to highest temperature and the highest spring population were recorded, the summer population was considerably smaller than in 1941 and 1944, when average maximum temperatures were several degrees lower, and initial populations in the spring were more moderate.

However, populations generally built up on early potatoes (Fig. 2), which reached their maximum growth in July. This fact indicates that large plants protect psyllids from high air temperatures. Other host plants, which are small at this time, permit the full penetration of heat and the sun's rays into the foliage. Before cultivated crops are large enough to shade the surface of the ground, the sun's

Table 1.—Effect of winter temperatures (December, January, and February) and preciptation on the potato psyllid infestation the following summer in the North Platte Valley, 1940–1944.

Year	Temperature		Total Precipitation	Average Psyllids per 100 Sweeps on All Hosts
	Mean	Lowest		
	°F.	°F.	Inches	Number
1942	24.3	−31	2.28	13.53
1944	26.3	−14	1.56	8.54
1940	29.5	−16	2.05	1.65[1]
1941	30.5	−25	.65	12.37
1943	32.3	−20	.77	.49

[1] No records on cull piles or matrimony-vine in 1940.

Table 2.—Relation between July temperature, maximum spring population, and the summer population of the potato psyllid, North Platte Valley, 1941–1944.

Year	Average Maximum July Temperature	Psyllids per 100 Sweeps Spring Population on Matrimony-Vine and Cull Piles	Summer Population on All Hosts
	°F.	Number	Number
1944	85.8	109	13.5
1941	87.4	90	12.6
1942	91.7	294	9.1
1943	92.4	4	.6

rays heat it, and this heat radiates into the plant foliage.

High temperatures apparently have little retarding influence on the development of psyllid infestations in August, since temperatures at this time are only slightly lower than in July (Fig. 1) and populations on all hosts gradually increase throughout the month. In 1944 the August temperature, average 0.9° F. above the July temperature and numbers continued to increase, while little change was shown during July, when the plants were much smaller. Cultivated crops, as well as noneconomic host plants, grow rapidly during the hot weather of July and August.

Populations increase at an accelerated rate during the first half of September with little interruption, except in some seasons by early killing frost. For example, in 1941 frost on September 9 forced psyllids to move from cultivated crops to matrimony-vine and wild groundcherry, which were not affected by the frost (Figs. 1 and 2). Only the tops of the late potatoes were killed; therefore, the psyllid was able to maintain its population, but with little increase in numbers. In 1942 a frost on September 17 was followed by a long period of temperatures below 60° F., and psyllids were forced to leave the plants. The population of psyllids also decreased in September of 1940 and 1944, when the temperature dropped to 60° or lower, although there was no killing frost. It is thought that these low temperatures may induce psyllids to move to overwintering quarters in the fall.

SUMMARY.—Surveys of the potato psyllid, *Paratrioza cockerelli* (Sulc), on cultivated crops and noneconomic hosts in the North Platte Valley of Wyoming and Nebraska from 1940 to 1944 indicate that the psyllid does not overwinter in this area and that initial spring populations come from some unknown source outside the valley. In the fall of 1943 a very low population of psyllids occurred on all host plants, but during the spring of 1944 the population was high. This could not have been the result of an increase in the local area during the winter months.

Potatoes growing in cull piles and the matrimony-vine, *Lycium halimifolium* Mill., are by far the most important noneconomic host plants of the potato psyllid in the North Platte Valley. These hosts collect the greater part of the initial population of adult psyllids in the spring, and serve as a source of infestation for other hosts, mainly early potatoes, in July. Wild buffalo-bur and groundcherry are not important host plants of the potato psyllid. The early potato crop serves to carry the psyllids over the hot July weather until later plantings of potatoes and tomatoes are large enough to support psyllid infestations.

There is no apparent relation between spring infestations of psyllids and temperature or precipitation during the preceding winter.

The spring movement of psyllids to the host plants under study began the first weeks in May and June. The population of adult psyllids increased very rapidly during the latter half of June, and reached a peak about July 1. The size of this spring population was affected by the temperature during May and June, the optimum temperatures for spring movement and development being between 60° and 70° F.

The principal factors affecting psyllid populations after July 1 are the size of the spring infestations, size of plants, and maximum temperatures for July. Above-normal temperatures at this time will reduce numbers to the extent that the subsequent build-up is very slow except on early potatoes, which are large enough to protect the psyllids from the hot sun's rays. A fall peak of infestations is reached about September 15.—10-24-46.

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An Insecticidal Check Method for Measuring the Efficacy of Entomophagous Insects[1]

PAUL DEBACH, *University of California Citrus Experiment Station, Riverside*

In biological control today, as in the past, statistical proof of the efficacy of entomophagous insects in the field is all too often lacking. Smith & DeBach, in 1942, recognizing the fundamental need for information of this type, stated: "Failure to present convincing evidence in support of conclusions with reference to parasite introduction is not, however, an indication of lack of appreciation of the desirability of some method of measuring, statistically, the effect of parasites or predators on their host populations. It is rather an indication of the difficulties inherent in the problem itself. . . ."

The effectiveness of insecticides in the field has long been measured easily by comparing the differences between treated and untreated or check plots. In biological control work, however, a simple method such as this has not been used because, according to Smith & DeBach (1942), "it has not ordinarily been possible to adopt this procedure, for the reason that the check plots are almost immediately invaded by the introduced enemies." These authors suggest other methods for measuring the quantitative effect of entomophagous insects on the survival of their host populations, principally, (1) correlation of host and parasite or predator population fluctuations over a period of time, and (2) exclusion of enemies by screening, to serve as a check; they also discuss the limitations involved.

A simple check method which is the exact inverse of the ordinary untreated check used in insecticide evaluations is now available for measuring the efficacy of certain entomophagous insects. According to this method, a treated (poisoned) plot, instead of an untreated (unpoisoned) plot, is used as the check, the treatment of necessity being one which will eliminate or greatly reduce the entomophagous insects involved, while having little or no effect on the host population. Comparison of such a treated plot with a plot having the natural enemies normally present, or purposely introduced, will show by the difference in the two host populations just how valuable the parasites or predators are.

Up to the present time DDT has furnished the principal means of utilizing this type of check, although Smith (1929) has suggested that arsenical sprays could be used on infested trees to eliminate vedalia, *Rodolia cardinalis*, and *Cryptochaetum* and thus measure their effectiveness aginst the cottony cushion scale, *Icerya purchasi*. DDT was the first insecticide to be tested by the writer in this regard because numerous field observations had indicated that subsequent to DDT applications certain host populations had increased, while their predators or parasites had been eliminated.

FIELD TESTS AND DISCUSSION OF RESULTS.—Population observations begun by the writer in March, 1946, involved the long-tailed mealybug, *Pseudococcus longispinus* (Targ.), and its complex of predators and parasites on citrus trees in the field, treated[2] with DDT (12.5 per cent in talc) dust or spray, or with talc dust or spray, or untreated. Talc was used as a diluent for the DDT and was also applied in the pure form to determine whether inert-residue effects were involved in population increase.

Comparable trees having similar initial densities of hosts and natural enemies were chosen for these studies. Treatments were applied March 11, 1946, and population samples were taken subsequently at monthly intervals. Estimates of pretreatment populations (table 1) were based on averages of other, comparable trees which had been sampled regularly. Counts were based on band samples, which give an accurate index of relative tree populations.

Results of tests in one grove are given in table 1. For purposes of simplification, data from dust and spray treatments using the same materials are combined. It is evident that by April the DDT treatments had greatly reduced the mealybug population and eliminated the predator population, although the percentage of parasitization subsequently increased each

[1] Paper No. 552, University of California Citrus Experiment Station, Riverside, California.

[2] Treatments applied in cooperation with Dr. Lee R. Jeppson.

month. This increase in parasitization undoubtedly resulted from the elimination of competition with predators. Since, in the absence or near absence of predators, and despite the continued activity of parasites, the mealybug population on the DDT-treated trees proceeded to increase during May, June, and July, it follows that the parasites were not a controlling factor at the host densities involved. On the talc-treated trees, the mealybug population was not reduced by April and parasites were little affected, but increase of the predators was virtually eliminated during April and May. A heavy build-up of the mealybug population during April and May showed that in the absence of sufficient predators rapid increase of the host occurred, even though parasites were present in normal numbers, as shown by comparison with untreated trees. On the untreated trees predators proceeded to increase rapidly and maintain themselves, mealybug population declined, and parasitization remained fairly constant during May and June. Comparisons of the three types of treatments readily indicate that during the period involved predators were primarily responsible for the decline of the populations of long-tailed mealybugs under natural conditions, whereas parasites played a minor role.

Table 1.—Relative population changes of the long-tailed mealybug, *Pseudococcus longispinus* (Targ.), and its natural enemies on untreated and on DDT- and talc-treated check citrus trees, 1946.

Monthly Counts	DDT-Treated Trees			Talc-Treated Trees			Untreated Trees		
	Mealybugs	Predators	Parasitization	Mealybugs	Predators	Parasitization	Mealybugs	Predators	Parasitization
	Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
March (pretreatment estimates)	75	2	6	75	2	6	75	2	6
April	10	0	22	170	2	8	124	1	3
May	75	0	73	525	3	26	108	82	28
June	180	3	80	269	49	41	55	31	29
July	381	6	96	25	14	39	9	13	78

It should be noted that in the above example this method permitted not only a measurement of the over-all effectiveness of the predator-parasite complex, but also a comparison of the two component parts. This was made possible by the unintentional use of two "insecticidal" checks, for at the time talc was not known to be "toxic" to predators.

Another example of the value of an insecticidal check in the measurement of the efficacy of an entomophagous species has resulted from experimental treatments, with DDT, of citrus trees infested with cottony cushion scale. Several cases have been followed in the field, one of which will serve as an example.

A generally heavy infestation of cottony cushion scale had developed in a navel orange grove in Tulare County by July, 1946, and the population of the predatory coccinellid *Rodolia cardinalis* had started to build up. On July 16, 1946, two plots[3] were sprayed with DDT, one at the rate of 2 lbs. per acre and the other at 4 lbs. This spray had very little effect on the cottony cushion scale but eliminated the predatory beetles. Meanwhile, on adjacent untreated trees, the *Rodolia* beetles population increased very rapidly, so that by August 21 there were practically no live cottony cushion scale to be found. No reduction of the cottony cushion scale population occurred during this period on the DDT-treated plots, although by August 21 some adult *Rodolia* and a few young larvae were again present in these plots, indicating that the DDT had become ineffective. Again, a simple presence-and-absence comparison shows very definitely the effectiveness of an entomophagous insect.

DDT, of course, is not the only insecticide which will be found to be practical. Rotenone (DeBach 1947) and arsenicals (Smith 1929) have also been found to have the necessary requirements for the measurement of the effect of *Rodolia cardinalis* on populations of cot-

[3] These plots were originally designed to test the effect of DDT on the cottony cushion scale, and were supplied by Dr. William H. Ewart.

tony cushion scale. Haug & Peterson (1938) have shown that against the predatory coccinellid *Hippodamia convergens* phenothiazine and derris were especially toxic, with *Black Leaf 40*, paris green, and calcium arsenate somewhat less so. Given a host of *Hippodamia* unaffected by any of these materials, the efficacy of the predator could be measured easily.

This method has its limitations. Adequate, practical population-sampling techniques are not always easy to develop for the host insect and its complex of natural enemies. Residues nontoxic to the host but toxic to its natural enemies may, entirely aside from the elimination of the natural enemies, make conditions more favorable for host population increase. In addition, it may not always be possible, or feasible, to obtain an insecticide which is nontoxic to a given insect pest but toxic to its parasites or predators, or to both. However, the surface has just been scratched. Insecticidal research has included tests of hundreds of materials against numerous insect pests. Many of these materials have been found to be nontoxic, or relatively so, to various host species. Certain ones, however, may be quite toxic to the parasites or predators of the hosts against which they are ineffective. The task now remains for workers in biological control to determine, either by laboratory tests or from field observations, which of these materials are suitable for a particular problem, and to apply them in the field for the practical evaluation of the effectiveness of the entomophagous insect involved.

Summary.—A new type of check-plot method is described, which utilizes treated or insecticidial checks for measurement of the efficacy of entomophagous insects. An insecticidal treatment, such as DDT, is used to eliminate or greatly reduce the populations of entomophagous insects involved, while having little or no effect on the host population. Comparison of a treated plot with one having introduced enemies or the normal complement of natural enemies shows, by the differences in the two host populations, just how valuable the parasites or predators are.

Field experiments are described in which citrus trees infested with the long-tailed mealybug, *Pseudococcus longispinus* (Targ.), were treated with DDT in talc, with talc alone, or were untreated. Three evaluations were made possible as a result, namely: (1) the effect of parasites alone, (2) the effect of predators alone, and (3) the effect of parasites and predators combined. Predators were shown to be the major limiting factor, since mealybug populations were kept down in their presence, but increased to a certain extent in their absence and in the presence of parasites.

Other field comparisons involved citrus plots infested with the cottony cushion scale, *Icerya purchasi* Mask., which were treated with DDT, or were untreated. The untreated plots showed a remarkable build-up of the predatory vedalia, *Rodolia cardinalis* (Muls.), and virtually the complete elimination of the cottony cushion scale. The DDT treatments killed the vedalia present and kept them from re-entering the plots and becoming effective throughout the remaining observational period. As a result, the population of cottony cushion scale remained very high.—10-22-46.

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Salt Marsh and Anopheline Mosquito Control by Ground Dispersal of DDT Aerosols[1,2]

FRANK BRESCIA, *Research Associate, Columbia University,*[3] *New York, et al.*[4]

Field tests were made with an aerosol generator to determine the practicability of stable aerosols, composed of oil-DDT droplets, dispersed from a ground vehicle, for the rapid control of adult mosquitoes over large areas.

The aerosol generator used was designed and developed (February to April 1944) at the Columbia University, Central Aerosol Laboratories. Details will be reported later by its inventors. Approximately equal quantities of oil, containing the dissolved DDT and water are pumped separately or as an emulsion through a vaporizing coil to form a mixture of superheated steam and liquid oil which is then passed into the atmosphere through capillaries of specific dimensions at regulated temperatures and pressures. Passage of the vapor and liquid phases through the capillaries produces the desired aerosol by mechanical disruption of the oil phase. The capacity of the No. 1 inventor's model used was 16 to 18 gallons of emulsion per hour. In later models, the use of a dual plunger pump to feed oil and water phases separately eliminated the need for emulsification.

These field tests were conducted in the region of Cocoa, Florida, May 1 to July 26, 1944, and in the Buckeye and Blackwell Swamps, near Decatur, Alabama, August 1 to August 22, 1944.

In the vicinity of Cocoa, Florida, the prevailing mosquitoes were the salt marsh species, *Aëdes sollicitans* and *A. taeniorhynchus*. *Anopheles atropus* and *Psorophora ciliata* were occasionally observed but in numbers insufficient for significant tests.

In view of the markedly different habits of the *Anopheles* as compared with the *Aëdes*, which might greatly affect the procedure required for their control, tests were carried out, in the swamps in the Tennessee Valley where the principal species was *Anopheles quadrimaculatus*. A further reason for making such tests was to see what effect local variations in terrain and meteorological conditions had on control by DDT aerosols.[5] It was appreciated that control requirements in the combat Pacific areas would doubtless be very different from those prevailing in any one locality in the U.S.A. It seemed desirable therefore, to test the method under two markedly different sets of conditions in the United States.

PARTICLE SIZE WITH REFERENCE TO FIELD OPERATIONS.—Particle size is of importance in field work from two points of view: (1) Relative toxic effects, (2) Relative distances the particles are airborne.

Preliminary tests on the toxicity of DDT aerosols of uniform particle size started in the Columbia University Laboratories in November 1943, using *Drosophila* as the test insect and quantitative studies on *Aëdes aegypti* were later carried out jointly with Mr. Randall Latta of the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture at the Beltsville Laboratories. These experiments showed that particles as small as 0.4 to 1 micron diameter were relatively ineffective as insecticides, because of poor deposition on the insects, as compared with the larger particles of 6 to 90 microns diameter.

The other factor in effectiveness is the distance the particles remain airborne. This factor is very important since control of adult insects on the wing can be brought about only by airborne particles. If the particles are larger than approximately 40 microns (*i.e.* in the range commonly designated as a spray or "heavy aerosol") they will not remain airborne for appreciable distances unless the wind speed is high, *i.e.* of the order of at least 15 miles per hr. Thus, using a high-

[1] Contribution from the Department of Chemistry, Columbia University.

[2] This work was done under a series of contracts between Columbia University and Division 10 of the National Defense Research Committee of the Office of Scientific Research and Development. Dr. Victor K. LaMer, Professor of Chemistry of Columbia University, had general supervision of the project.

[3] Present address Department of Chemistry, City College of New York.

[4] This paper was prepared jointly by Dr. F. Brescia, Dr. Victor K. LaMer, George E. Bohart, Irwin B. Wilson, Kenneth C. Hodges and John Rowell. The latter five names do not appear for bibliographical reasons.

[5] All particle sizes in this paper are given in microns diameter. Subsequent field tests with larger and improved aerosol generators on mosquitoes, as well as other insects, will be reported separately as such material becomes declassified.

pressure sprayer (air pressure 380 lbs., output 5 gal. per min.) and an oil mixture containing a red dye, on an open beach area with a wind velocity of 5 to 7.5 miles per hour, most of the mixture which had a particle diameter of the order of 125 microns rained out within 35 ft. of the line of the course of the jeep from which it was applied. The jeep was moving at a speed of 12.5 m.p.h. This limited down wind travel of the spray was easily seen because of the intensity of the red coloration on the sand. This visual observation is further substantiated by the quantity of the dye which deposited on plates laid down at different distances down wind. These data are given in table 1 and are plotted in figure 2A.

Table 1.—Quantity of dye in micrograms per square centimeter obtained at various distances down wind from a high pressure sprayer. Test #8: May 29, 1944.

DISTANCE	MICROGRAMS DYE/CM.^{2}
25 ft.	14
50	14
100	2.2
200	0.11
300	.035
400	.0015
500	0.000

Furthermore, aerosols containing particles which are larger than about 10 microns diameter are not capable of penetrating forested or jungle areas to any appreciable extent but rather will deposit out on the vegetation.

These two size factors (*i.e.*, if too small, aerosol is inefficient; if too large, the fraction of the aerosol remaining airborne will sharply decrease with distance) are conflicting. Best results against adults in the field are to be obtained with particles 10 microns in diameter regardless of terrain and wind speed. (See also section on deposition and larval control.) But, where larval control in open country is the primary objective, a larger particle size should be used and this should be increased with increasing wind speed as follows:

Wind Speed	*Particle Diameter*
1 to 3 m.p.h.	16 microns
3 to 6	24
6 to 10	32

EMULSION COMPOSITIONS AND PARTICLE SIZE.—Investigations of aerosol production showed that the mass average particle size is a function of a number of variables, for example, the volume ratio of steam to oil projected through the outlet nozzles and the viscosity and surface tension of the oil-DDT mixture. The greater the proportion of steam the smaller the particle size. Lower viscosities and surface tensions also favor formation of smaller particles.

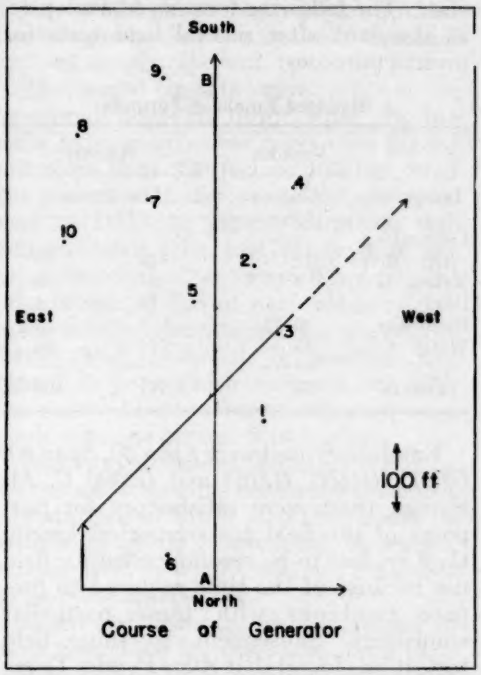

FIG. 1.—Tree hole location (1–10) and line AB of posted positions in test No. I. Broken line indicates general wind direction.

It is thus possible to vary the particle size considerably by adjusting the operating conditions of the generator or modifying the composition of the emulsion or both.

At proper operational temperature, the extent of DDT decomposition as shown by chemical analysis was negligible.

The emulsion used in most of these field tests was about 50–50 oil and water by volume. Lubricating oil (10W) dissolves DDT very slowly to an upper limit of about 5 per cent. To increase the rate of solution and the quantity of DDT which can be dissolved, the DDT is first dissolved in xylene. The DDT content thus can be raised to 10 per cent of the oil by weight, and even higher.

The xylene vaporizes much more rapidly than the lubricating oil and hence is not present to any appreciable extent in the aerosol droplets. The lube oil has an exceedingly low vapor pressure and hence does not evaporate. After the xylene evaporates, the particle size remains constant. The following formula was adopted as standard after several field tests for present purposes:

Standard Emulsion Formula

	Volume	Weight	
Ingredient	Gallons	Lbs.	Per cent
Lubricating Oil—10W	15	108	40
Xylene	3	21.5	8
DDT		11	4
Emulsifier	0.75	6.2	2
Water	15	124.5	46
Totals	34	271	100

Emulsifiers used were *Span 20*, *Span 80*, *G1200*, *G1500*, *G1165* and *G2000 C*. Although these were satisfastory for purposes of the field tests reported herein, they are not to be recommended for field use because of the time required to prepare emulsions with these particular emulsifiers. Subsequent to these field tests it was found that *Atlas Powder Tween 85* (2.5 per cent of the oil by volume) eliminated much of the labor of preparing the emulsions.

The particle size was determined by holding a can, which contained a slide with an oleophobic (zinc stearate) surface, in the aerosol cloud for 2 to 3 seconds and then placing a tight fitting lid upon the can. The can was at least 6 inches diameter and 6 inches deep. It was allowed to stand at least 30 minutes before the slide was examined microscopically. On such an oleophobic surface, the contact angle between droplet and surface is fairly constant and the apparent diameter is approximately twice the true diameter. The use of barium-copper-ferric stearate oleophobic surfaces is not always satisfactory when emulsifiers other than soap are used.

Meteorological Conditions and Field Operations.—Meteorologists express the state of atmospheric stability by the terms, "Inversion," "Lapse" or "Neutral." Under inversion conditions, the temperature of the air near the ground is colder than that of the layers above it, and the result is a stable atmospheric condition. On the other hand, lapse corresponds to a turbulent atmosphere produced by the heating of the earth by the sun so that the lower layers of air are warmer than the upper layers.

In making tests (or in actual control work), inversion or at least neutral conditions are necessary and wind speed above 2 m.p.h. are desirable to disperse the aerosol effectively. Operations with wind speeds less than 0.1 m.p.h. are not practicable. Under lapse conditions, the bottom of the aerosol cloud will rise, leaving very little of the toxic material near the ground level at which the insects are to be found. A sufficient degree of atmospheric stability sets in after sunset, making it possible to operate at any time between sundown and sunrise.

Wind speed is a very important factor in determining the ability of the aerosol to remain close to the ground. It is possible to operate during sunlight with winds of greater velocity than 5 m.p.h. since under these conditions more or less neutral conditions exist. On cloudy days neutral conditions usually prevail.

Proper meteorological conditions for operation were checked by setting off an *H-C Hand Smoke Grenade* and observing whether the bottom of the smoke cloud lay close to the ground and whether there was much, if any, turbulence causing the cloud to rise rapidly.

The dependence of successful test operations upon suitable wind conditions and atmospheric stability should be further emphasized. Several tests had to be abandoned because of lack of any wind. Others were practically or completely upset by sudden changes in direction of the wind.

The fact that several tests had to be given up because of wind shifts does not in any way detract from the applicability of the general method of large area coverage by ground dispersal of aerosols. A change in wind direction in an actual operation can be compensated for by moving the generator to correct this shift. On the other hand, in test work, if the wind shifted, plates, slides, cages, and barrels were no longer in the path of the aerosol and, hence, the test as planned had to be abandoned.

It is, of course, obvious that when there is no wind, there can be no operation either for test or for clearing an area of mosquitoes in actual control work.

Even though time may be lost during an actual operation from periods of no wind or from moving the generator to compensate for a change in the wind direction, the coverage is so large and efficient that it will still be possible to cover many more acres per man hour than is possible with spray crews using hand or power sprayers.

HABITS OF MOSQUITOES AND CONTROL OPERATIONS.—The location of the adult mosquitoes at different times of the day and their migratory habits must be known not only to determine the best time and place for practical operations but to evaluate correctly the test results. It is recommended that a study of the migratory habits of the insect being treated always precede field tests in the chosen locale.

With the small dosages found necessary to achieve kill on the wing, residual effects become unimportant. Hence, the aerosol has to be projected and carried by the wind to the place where the mosquitoes are located. This refers not only to the general locality in which the insect is at the time, but also to the character of the particular spot wherein the insect is located. For example, using large spray particles it is more difficult to deposit a lethal dose of DDT upon a mosquito while it is resting inside a hollow log or in a tree hole than upon the mosquito on the wing. The droplet, in order to make contact, must be carried by the wind or eddy currents into these hiding places. Later (tables 8 to 10) it will be shown that kill in such places was achieved by generation of aerosols of proper particle size.

Broadly speaking, migratory habits can be divided into two types, diurnal movements within limited areas, and irregular roving movements. The diurnal movements are the ones which determine when and where a certain localized group of mosquitoes should be treated. The nomadic movements affect the rate at which mosquites outside the treated area may infiltrate into the treated area. This rate determines how often a given area has to be treated to keep it reasonably free from mosquitoes.

PROCEDURES IN FIELD TESTS.—Early exploratory tests (May 1944) were made by generating aerosol from a fixed point and determining the toxicity to caged insects at various distances down wind. Later when natural mosquito populations were available, cage mosquitoes, were also used to prove that the aerosol was lethal and not simply repellent.

The caged insects were set out at measured intervals down wind. In the early experiments, test cages were placed not more than 300 feet or 400 feet from the generator. Later on, as the effectiveness of DDT at greater distances was demonstrated, the test cages were set progressively farther away. When natural populations of larvae were not available in the testing grounds used for the adults, larvae were collected, if possible, and placed in pans which were set out with the cages. All tests herein reported were made with the generator in motion.

For short distances the cages could be set out a few minutes before the generator was started, in which case they could be arranged directly down wind. Barring a sudden shift in wind direction, that procedure was satisfactory.

When test distances were increased to more than 1500 ft., cages and larva pans had to be placed in position an hour or more before the test was started. This involved ascertaining as far as practicable the probable wind direction. Local weather stations were consulted for predictions of the probable wind direction. Stakes were then set out at known intervals on three lines forming 45 degree angles. These stakes marked the stations at which cages and larva pans were subsequently placed. When the test was made, the wind direction, if forecast with any reasonable degree of accuracy, would be in the direction in which one or another of the lines of cages was laid out.

The distribution of aerosol over the terrain was determined in a variety of ways, including visual observation with the aid of high powered *Dewar* searchlights, detection by odor, and deposition on microscope slides.

More accurate permanent evidence of the passage of aerosol was obtained by adding a blue dye (*Calco Blue NA*) to the emulsion and measuring deposition (see section on deposition and larval control).

The toxicity of the aerosol was determined by observing its effect on the following:

(1) Natural free population of both adult mosquitoes and larvae. Measurements of salt marsh adult mosquito population were made before and after each test by counting the number of mosquitoes landing on the back of the shirt and trousers of an observer after he had remained motionless for 1 minute. A (+) after the count figure indicates that there were many mosquitoes in the air in addition to those which had already landed. With *Anopheles quadrimaculatus* adult counts were made in the natural resting places before and after each test.

(2) Adult mosquites in cages and kegs, and mosquito larvae in clear water in pans. (For the salt marsh species, a small amount of brackish water was added.)

With the pest mosquitoes, a factor which may affect the accuracy of the landing rate measurement is the tendency of these mosquitoes to follow the observers from station to station, so that the same insects may be recounted several times. This error is important only when but few insects are present and was eliminated as far as possible by shaking off the mosquitoes and running to the next stations. However, for most of the tests, sufficient workers were present to make movement from station to station unnecessary.

For kills in hiding places, such as holes in trees, a survey of the population of natural holes before and after tests is probably more satisfactory than tests made only with nail kegs covered with wire gauze. The shape and location of natural hiding places unquestionably has a great effect on the way aerosol penetrates all the nooks and crannies where the mosquitoes spend the day. Where possible, both methods were used.

Anopheles quadrimaculatus, unlike the salt marsh varieties, is easy to trap in view of its predilection for hollow logs and other similar places. Investigators at the T.V.A. demonstrated that if an empty damp nail keg is laid on its side in a shaded spot, it will contain in the daytime large numbers of anopheline mosquitoes. For test purposes, these were transferred to cages or the keg was covered with a screen and used as a cage.

To avoid any error that may result from using the same cages in different tests, only new unexposed brass cages were used for each test. Size of cages was 6 inches long by 2.75 inches diameter. Also, once exposed, a barrel was no longer used for test purposes, thus avoiding any question involving "residual effect."

FIELD RESULTS I—CONTROL OF SALT MARSH MOSQUITOES.—The entomological results of field tests made with the salt marsh mosquitoes are now given with pertinent data. As used here, length of front refers to the number of feet traversed by the generator carrier.

Test A (June 9, 1944): An adult control test using the natural (salt marsh) mosquito population.

Terrain: The comparatively dense forest with a closed canopy located on the west side of Florida Route 140 and lying south of the causeway (Route 70).

Operational conditions

Length of front: 1000 ft.
Wind speed: 0–106 ft. per minute (outside forest)
Inversion conditions: poor
Time of test: 19:17–22:00
Emulsion used: 50 parts oil–50 parts water by volume, DDT content 6 per cent of the oil wt.
Dosage: 10 gals of emulsion per 1000 ft.
Particle size: 2 micron diameter

Entomological results: Adult mosquito landing rate counts were made at about 55 different locations covering the south, central, and north sections of the 1000 by 1000 ft. test area. Check counts were also made at 10 different locations in the forest directly south of the test area.

The mosquitoes in the test ground were not bred in its vicinity because of the absence of larvae in the area and in the immediately surrounding waters. They had, therefore, migrated into the test area, most likely from the mosquito breeding areas on Merritt Island, located across the Banana River 3 miles west of the test area.

Table 2 gives the average landing rate for the different locations. Mosquitoes were present throughout the test area prior to the test but 90 minutes after the test, the landing rate was zero and only one or two buzzing sounds were heard throughout the test area whereas the control area showed no appreciable change in adult population. Also, it was found that the areas immediately southwest of the test area as well as the area to the

east were cleared of mosquitoes by the spread of the aerosol cloud. Hence 1000×1000 ft. is the estimated minimum area over which satisfactory adult salt marsh mosquito control was obtained in this test.

The return of an adult population 12 hours after the test shows clearly that no residual effect is to be expected from such a dosage as was used in the test and is illustrative of the rapid rate of infiltration, characteristic of salt marsh mosquitoes. Also, the twelfth hour count was made well after sunrise at which time migration into the shaded areas of the forest had already occurred (see checks in table 2).

Table 2.—Average landing rates (mosquitoes per minute) for about 55 locations. Test A, June 9, 1944

	Before Treatment	After Treatment		
		90 Minutes	12 Hours	16 Hours
Test Area	12	0.4 (97 per cent reduction)	25	28
Checks	7	7	14	22

Actually, the presence of the large population found in the morning following the test could have been predicted from the known migratory habits of these salt marsh mosquitoes. The absence of a residual effect was confirmed by the Orlando Laboratories of the Department of Agriculture with leaves taken from trees located 100, 200, 300, 400, and 500 ft. down wind.

Test B (June 16, 1944). *Object:* To demonstrate residual toxicity to adults.

Terrain: Test area was the light-dense forest located north of Florida Route 70 and east of Route 140.

Operational conditions

Length of front: 400 ft.
Wind speed: 0 to 120 ft. per minute (outside forest)
Inversion conditions: good
Time of test: 22:10 to 23:25
Emulsion used: 60 parts oil–40 parts water by volume; DDT content was 5 per cent of the oil by weight
Dosage: 52.5 gallons per 1000 ft.
Particle size: 6 to 8 micron diameter

Entomological results: Mosquito counts were made at 17 different points in the test area (table 3). Check counts were made at 9 different locations in the light forest across Route 70, opposite the area.

The counts along the north and northeast lines were made immediately before, and 20 minutes after, the test. The follow-up counts were made in the morning after full sun was up and at night although a more logical time for the follow up counts would have been late afternoon, but prior to sundown. Nevertheless, it is possible to draw definite conclusions from the data (table 3) obtained:

(a) Kill on the wing was probably obtained to at least 1000 ft. down wind although actual counts were made to only 600 ft. which show practically 100 per cent control 20 minutes after the test.

(b) Very satisfactory residual effect was obtained for a period of at least 12 hours following the test over an area of 400 ft. by 200 ft. (positions 7 to 4) downwind. This is emphasized by the fact that the mosquito population in the check area increased during this period by factors of 3 to 4. After 24 hours, a good residue effect was still evident along the northeast line only, and after 48 hours the counts were practically the same as before the test. About 4 pounds of DDT were expended to obtain a brief protective period over about 2 acres of ground. From this experiment it can be concluded that for longer protective periods with respect to salt marsh mosquitoes it would be more practical to treat extensive areas for kill on the wing than to deposit sufficiently large quantities of DDT from the aerosol generator over limited areas.

Local ground depositions (see section under deposition and larval control) varied from 0.32 lb. DDT per acre at 40 feet to 0.025 lb. at 200 feet downwind.

Test C (July 26, 1944) *Object:* An adult mosquito control test; to reproduce the results of Test A.

Terrain: Test area was the light-dense forest located north of Florida Route 70 and east of Route 140.

Operational conditions

Length of front: 500 ft.
Wind speed: 30 to 135 ft. per minute outside forest
Inversion conditions: poor
Time of test: 21:31 to 21:55
Emulsion used: 50 parts oil–50 parts water by volume DDT content being 10 per cent of the oil wt.
Dosage: 10 gals of emulsion per 1000 ft.
Particle size: 6 to 12 micron diameter

Entomological results: In this test satisfactory adult control was again obtained in a forest. Adult counts were made 20 minutes before and after the test at

Table 3.—Average landing rates. Test B. June 16, 1944.

Position	Distance Down Wind, Feet	Before Test (Night)	After Test				
			20 Min. (Night)	12 Hours (Morning)	24 Hours (Night)[1]	36 Hours (Morning)[1]	38 Hours (Night)[1]
NE 7	40	28	0	1	9	12	30
6	90	24	0	2	5	17	29
5	140	20	0	1	6	15	17
4	190	18	0	7	16	50	23
3	240	15	0	20	35	100	36
2	340	18	0	35	32	150	16
1	440	50	0	100	50	200	42
8	490	20	0	30			
9	540	24	0	50			
10	600	22	0	40			
Up wind	−15				33	45	30
N 7	40	+[2]	0	0	8	31	37
6	65	+	0	1	26	46	67
5	115	+	0	1	20	95	30
4	165	+	0	3	50	160	36
3	215	+	0	13	23	170	32
2	315	+	1 buzz	15	47	over 200	47
1	415	+	1	80	80	over 200	49
Checks		22	16	72			
		16	20	86			
		25	27	100			
		12	24	95			
		25	34	100			
		19	36	75			
		11	22				
		18	26				
			50		60	150	70

[1] These counts were made over the complete body.
[2] Insufficient personnel to make complete counts; the + indicates a rate of at least 15.

several positions and the results are given in table 4. Check positions were established in the forest up wind of the test area and the check counts remained constant, through this same period, at about 100 in one location and about 60 at a second location. Hence, satisfastory adult control was obtained to the measured 840 ft. down wind.

At dawn following the test, the mosquito adult population, as expected, was back to its usual dawn level.

Table 4.—Average landing rates. Test C. July 26, 1944.

Feet Down Wind	Before Test	After Test			
		15 min.	20 min.	90 min.	2 hrs.
90	20[1]	0	0	0	0
160	22[1]	0	1	1	1
225	18[1]	1	0	1	1
460	24[1]	1	1	2	2
600	20[1]	2	1	1	1
840	25[1]	5	2	2	4

[1] Denotes about 50 mosquitoes flying around ankles but not landing.

The next series of tests (Tests D, E, F, G, H) were conducted in an open marsh area in and about Sykes Creek (Merritt Island, Fla.). The marsh consisted mainly of pickleweed with *Distichylus* grass in isolated spots. The edges of the marsh were generally lined with mangrove and laurel trees. The main objective of these tests was to determine the maximum distance of control of salt marsh mosquitoes obtainable with a given dosage. A skiff was used as the generator carrier. Positions to about 5000 ft. were staked out for three different directions, which would permit operations for the winds found to be prevalent from meteorological data.

Test D (June 30, 1944). A dosage of 24 gallons of emulsion over a front of 3900 ft. and 10 gallons over another 2300 ft. was too small to produce any striking effects. In Test E (July 4, 1944) a dosage of 15 gallons of emulsion over a front of 1500 ft. did not produce satisfactory results beyond 1000 ft. down wind. In Tests D and E, the emulsion used was 50

parts water–50 parts oil, the DDT content being 5 per cent of the oil by weight.

Test F (July 6, 1944). With an increased dosage, it was noted that the mosquito landing rate decreased to practically zero during the test but rose very rapidly, within 15 to 20 minutes after the test, to the original count. Thus, counts made at several different cross wind locations at 1500 ft. down wind decreased from an average of about 55 before the test to 0 to 5 after the test, but increased very rapidly to practically 55. The same phenomenon was experienced at the 2600 ft. down wind mark. This rapid return of mosquitoes clearly indicates that the mosquitoes were not being killed. The aerosol, easily detectable by smell and high powered spotlights, remained about a foot above the pickleweed. The mosquitoes, upon smelling the aerosol, dropped into the marsh vegetation and in that position were safe from the aerosol cloud which remained above the vegetation. After the cloud passed, the mosquitoes could safely re-emerge.

Test G (July 8, 1944) *Object:* As a result of Test F, it was decided to operate during the early morning hours, when inversion is stronger, as well as the late night hours and to use caged mosquitoes to demonstrate that the rapid return of adult mosquitoes is due to an inversion condition that was not strong enough to carry the aerosol down into the marsh vegetation as well as demonstrate the killing power of the aerosol produced.

Operational conditions

Length of front: 300 to 800 ft. This was varied because of the variable wind (WSW to WNW, occasionally SW to NW). By varying the length of the course, it was possible to keep the observation positions in the aerosol cloud.

Wind speed: 250 ft per minute.

Time of test: run (a) 04:02 to 05:05; run (b) 05:30 to 06:25

Inversion: Fair during run (a) but aerosol did not get below the pickleweed level. Good during run (b); aerosol penetrated into the pickleweed to the ground.

Emulsion used: 50 parts oil–50 parts water by volume; DDT content was 10 per cent of the oil by weight.

Dosage: A total of 32 gallons of the emulsion was put out for both runs which is calculated to be 9 to 10 gallons of emulsion per 1000 ft. of front when corrected for the spread caused by the constant shift of the wind between WSW and WNW.

Particle size: 12 to 14 micron diameter.

Entomological results: Mosquito counts were made at three points down wind. Also, two cages of mosquitoes (obtained from the existing natural population) were held in the aerosol clouds at the 1500 and 2600 ft. positions. The results for the natural adult population and caged mosquitoes are given in table 5. After the test, the personnel stationed at 2000 ft. walked down wind to 3400 ft. and heard only two buzzing mosquitoes; the landing rate was zero to this mark. Attempts to kick up mosquitoes out of the pickleweek produced no mosquitoes. Pretreatment counts were not made at 3400 feet location but from uniformity of terrain and mosquito species, and from past and later experiences with this particular spot, it is safe to assume a high population was previously present.

The fact that the caged mosquitoes in cage 1 were affected and eventually killed after run (a) whereas over the same period of time the mosquitoes in cage 2 lying upon the pickleweed were not affected and the natural mosquito population started to increase rapidly after run (a), definitely proves that the comparatively poor results obtained upon the natural mosquito population in Test F and in this run (a) are due to relatively poor inversion conditions and not to a lack of killing power of the aerosol produced. This is further substantiated by the high mortality obtained on all caged mosquitoes and by the results of run (b) conducted at a time when inversion was strong enough to keep the aerosol close to the ground. After run (b) the counts on the natural population were zero and remained at zero until the personnel left the test area, 50 minutes after the end of the test.

Thus, very satisfactory control was obtained to a distance of at least 3400 ft. down wind for an output corresponding to 9 to 10 gallons per 1000 ft. of front. Such results are obtainable on the marsh field only when inversion conditions are strong enough for the aerosol to "hug" the ground or the marsh vegetation.

Cage 1. Contained 15 adults and was held in the arosol at 1500 ft. Some mosquitoes were affected after 1 to 2 minutes in the arosol and by the end of run (a) all were affected. Final count after the test showed 100 per cent mortality.

Cage 2 contained 9 adults and was laid upon pickleweed. After run (a), they were not apparently affected and were held in the aerosol during run (b). All were affected by the end of the run and final count showed 100 per cent mortality.

Cages 3 and 4 contained 13 and 15 adults respectively and were held in the aerosol at 2600 ft. during runs (a) and (b). The reactions were the same in both cages. As each aerosol cloud passed, the mosquitoes dropped to the bottom of the cage but came up again. The final count showed 85 per cent mortality in Cage 3 and 100 per cent in Cage 4.

counts. The test was again made in two runs; (a) at pre-dawn, 05:21 and 06:13 and (b) at post-dawn, 06:58 to 07:43.

At least two cages of mosquitoes captured in the area just prior to the test were also located at each position.

The test results on both the natural population and caged mosquitoes are given in tables 6 and 7.

In addition to these results, several members of the field party walked, after the test, from the 2400-foot position to 5000 feet down wind making counts at every 500 feet. The average count on the observers over this distance was two.

Table 5.—Caged mosquito results. Test G. July 8, 1944.

Position Down Wind Feet	Before Run (a) (03:45)	5 Minutes after Run (a) (05:10)	25 Minutes after Run (a) and at Start of Run (b) (05:30)	20 Min. after Run (b) (06:45)	50 Min. after Run (b) (07:15)
1500	120+	0	40	0	0
2000	55+	10	4	0	0
2600	70+	18	46	0	0
3400					2 buzzes, 0 landing rate

Test H (July 18, 1944) *Object:* A repetition of Test G to ascertain if the results on adult mosquito control of Test G could be duplicated.

Operational conditions

Length of front: 500 ft.
Wind speed: 130 to 190 ft. per minute. Maximum 245 ft. per minute.
Inversion: good during both runs; aerosol was down to the ground
Time of test: run (a) 05:21 to 06:13 (b) 06:58 to 07:43
Emulsion used: 50 parts oil–50 parts water by volume; DDT content was 10 per cent of the oil by weight.
Dosage: A total of 32 gallons of the emulsion was put out for both runs, which, corrected for the constant shift of the wind between west and southwest, is equivalent to a dosage of 8 to 9 gallons of emulsion per 1000 ft. of front.
Particle size: 6 to 8 micron diameter.

Entomological results: Positions for adult mosquito counts were located at 1400, 1700 and 2400 feet. At the 1400-foot position, counts were made under a large laurel tree (which by 07:00 in past mornings yielded landing rates of 200 to 300 mosquitoes per minute), at the edge of this tree and in the pickleweed about 40 ft. from this tree. A position, up wind of the generator, was established for check

This count includes one made beside a large laurel tree at the 5000-foot mark at a time of the day (09:00) when the laurel tree count would have been in the hundreds. Also, at about 5200 feet an average count of one was obtained by two observers at another laurel tree; at 5300 feet, in a shaded spot, an average count of two was obtained by three observers. These counts were made at about 09:00 and at about this same time (09:30), the swamp area, located south of the treated area, showed counts of 50++ in several shaded spots.

About 24 hours later, the laurel tree at the 5200-foot mark had a count of 100+++ and a count of 40+ was obtained in the shaded spot at the 5300 foot mark.

From these results, it can be concluded that 100 per cent mortality was obtained on natural population to about a half mile down wind and that at least 95 per cent mortality was obtained for an additional half-mile down wind for an output corresponding to 8 to 9 gallons of emulsion per 1000 feet of front. Residual effects, as was to be expected, were not important.

EFFECT OF OIL-DDDT AEROSOLS ON

FISH.—Although no quantitative studies were made regarding the effect of the DDT-oil aerosol on fish, it can be stated that, as used on Sykes Creek, the aerosol had no effect on the fish-life in these waters. Sykes Creek abounds with trout-like fish known as mullet. Occasionally while we were rowing to and from various positions, fish would bounce into the boat. The order of magnitude of the quantity of oil-DDT deposited on the water surface of the creek was about 10 to 15 microgram per square centimeter close to the boat carrying the generator. In addition, at least two gallons of the emulsion were pumped into the creek water on starting and shutting off the generator. No dead fish were observed. It is possible, but not very probable that affected fish could have gone beyond our range of observation.

FIELD RESULTS II—ANOPHELES QUADRIMACULATUS CONTROL.—The next series of field tests was conducted in the Blackwell and Buckeye Swamp territories and forested areas, in the TVA experimental grounds near Decatur, Alabama, to determine the effect of the aerosol upon the natural and screened adult and larval population of *Anopheles quadrimaculatus*.

Test I (August 24, 1944): A control test on *Anopheles quadrimaculatus* adults.

Terrain: A light deciduous forested area with a thick vegetative growth at the edge of which the generator run was made; high somewhat broken canopy.

Operational conditions

Length of front: 500 ft.
Wind speed: 30 ft. per minute or less in the forest
Inversion: Fair to poor
Time of test: 18:00 to 20:25 (Operation was interrupted once to clear a clogged nozzle and once to clean the burner strainer.)
Emulsion used: 50 parts oil–50 parts water by volume; DDT content was 10 per cent of the oil by weight
Dosage: 30 gallons of emulsion, which, corrected for the wind spread, is equivalent to about 30 gallons of emulsion per 1000 feet of front.
Particle size: 10 to 14 microns diameter.

Table 6.—Average landing rates. Test H. July 18, 1944.

POSITION DOWN WIND, FEET	20 MIN. BEFORE TEST	DURING RUN (a)	DURING RUN (a)	5 MIN. AFTER RUN (a)	40 MIN. AFTER RUN (a) AND START OF RUN (b)	DURING RUN (b)	END OF TEST	45 MIN. AFTER TEST	110 MIN. AFTER TEST	26 HRS. AFTER TEST
Time	05:00	05:45	06:05	06:20	06:55	07:15	07:45	08:30	09:35	
1400										
a) Under Tree	+	5	2	3	2	1	0	0	0	25+
b) Edge Tree	35+	4	2				0	0	0	
c) Pickleweed	+	3		16	2	0	0	0	0	8
1700	50+	6	1	5	0	0	0	0		
2400	112+	36		23	1	0	0	0		
Checks										
a) Pickleweed Creek Edge	26							23		
b) Open Marsh (Pickleweed)	140+		113+			70		72		
c) Tree	63+			100+	133+			150+		

Entomological results: This was a test successfully carried out against natural and screened adult *Anopheles quadrimaculatus*. The test was conducted during the evening hours when the adults migrate out of their resting places in the woods and for several days thereafter the number of adults in the natural resting places was less than 10 per cent of the number present before the test.

For this test, adult mosquitoes (*75 per cent Anopheles quadrimaculatus, 25 per cent Culex*) were trapped in cages and barrels posted at several different distances along the line AB (Fig. 1) in the area under treatment. The cages were kept at ground level and in trees 6 to 7 feet from the ground. The barrels were empty nail kegs (the open end of which

was covered with screen wire) placed at different angles with respect to the wind direction. Ten tree holes and rotted logs of various shapes and sizes were located in the treated area. Mosquito counts in these natural resting places, the relative positions of which are shown in figure 1, swamp was located beyond the 1200-foot station.) Also a protective period (see also Residue Effects) against the natural population of 4 to 5 days was obtained.

During the first check-up period, about 4 hours after the test, the following miscellaneous insects were found dead mainly

Table 7.—Caged mosquitoes results. Test H. July 18, 1944.

Position Down Wind, Feet	During Run (a)	During Run (a)	20 Min. after Run (a)	40 Min. after Run (a) and Start of Run (b)	End of Test	3 Hrs. after Test[1]	Per Cent Mortality 3 Hrs. after Test
Time	05:40	06:05	06:35	06:55	07:45		
1400 Feet a) Under Tree	1 down	2 down	2 down		4 up	15 dead 3 alive	85
b) On the Tree	1 down	7 down	1 up		All down	22 dead 0 alive	100
c) On Top of Pickleweed		2 down		4 down	1 up	9 dead 1 alive	90
d) Exceptionally well protected under the Pickleweed		3 down		1 down	4 down	2 dead 3 alive	40
1700 Feet a) Face Level		4 down				22 dead 2 alive	90
b) Ground Level in Pickleweed		5 down				21 dead 0 alive	100
2400 Feet a) Face Level	3 down	5 down	6 down	10 down		13 dead 0 alive	100
b) Ground Level in Pickleweed	1 down	2 down	1 down	3 down		14 dead 2 alive	85
Check Cages	0 down	0 down	0 down	0 down	0 down	0 down	0

[1] Those recorded as alive were down and affected with typical symptoms of DDT poisoning.

were made before and after the test. High mortalities were evident in general in the test area during and immediately after the test (Tables 8 to 10). In these tables, "A" represents *Anopheles quadrimaculatus*, and "C" represents *Culex*. Check cages on ground and in trees showed no mortality at end of test and 5%–20% four hours after the test.

The results clearly demonstrate that very effective control was obtained on the natural adult *Anopheles quadrimaculatus* population and on the trapped mosquitoes of this species over all posted stations at a minimum distance from the line of generator operation. (A deep water up to the 600-foot station and on the water in larval pans: a wasp, a small beetle, a flea beetle, an ant-like beetle, leaf hoppers, midges, gall midges, a tachinid fly, a greenbottle fly, a robber fly, a horsefly, gall gnats, moths, a stink bug, an *Aëdes triseriatus*, a spider and an ant.

Since the distance over which these dead insects were found is much shorter than that over which mosquito control was achieved, it can be inferred that the lethal dose for these insects is greater than that for adult mosquitoes. Also, the location of a dead spider or a dead wasp here and there does not necessarily mean that practical control of these insects was

achieved. Instead it indicates that the proper use of the aerosol generator with the recommended dosage for mosquito control will not have a serious effect on "biological balance" of the insect world.

Test J (August 28, 1944). As in Test I, this test was also successfully carried out against natural adult *Anopheles quadrimaculatus* population. The previous test was conducted over the period in which the adults migrated from their resting places. Test J was, however, conducted in the morning hours after the adults had returned to their resting places. The area chosen was about 2000 by 500 ft. and contained about 20 tree holes and rotted logs of various descriptions scattered throughout. As in the previous test, tree hole counts were made for several days prior to the test to establish a satisfactory, more or less constant, population. Down wind distance of tree holes was up to about 700 feet.

Table 8.—Caged *Anopheles quadrimaculatus* results. Test I. August 24, 1944.

Position Location Along the Line AB (Figure 1)	Position of Cage	4 Hours after Test		
		No. of Mosquitoes		
		Dead	Alive	Mortality
100 ft.	Tree	18	0	100%
	Ground	20	0	100
200	Tree	26	0	100
	Ground	10	0	100
400	Tree	8	0	100
	Ground	20	0	100
600	Tree	25	0	100
	Ground	9	0	100
800[1]	Tree	5	3	60
	Ground	10	7	60
1100	Tree	12	1C, 1A	85
	Ground	31	4C	90
1200	Ground	12	0	100

[1] This position was located at the far side of a road which cut across the test area. "Funnelling" of the aerosol cloud occurred at this position and accounts for the comparatively low mortality.

Object: Control test on *Anopheles quadrimaculatus* natural population.

Terrain: A lightly forested area.

Operational conditions

Length of front: 2200 feet
Wind speed: 150 to 190 ft. per minute in the forest
Inversion: Good to fair to poor
Time of test: 07:10 to 08:10
Emulsion used: 50 parts oil–50 parts water by volume, DDT content being 10 per cent of the oil by weight
Dosage: 9 gallons of emulsion per 1000 feet of front
Particle size: 6 to 14 microns diameter

Entomological results: The data given in table 11 shows very satisfactory control (practically 100 per cent) and a protective period of 1 to 2 days was obtained on the natural population treated at a time when adults were present in their resting places.

Table 9.—Results on *Anopheles quadrimaculatus* mosquitoes trapped in barrels. Test I. August 24, 1944.

Position Location Along the Line AB	Position of Open End	4 Hours after Test		
		No. of Mosquitoes		
		Dead	Alive	Mortality
100 ft.	Facing Wind	100	0	100%
	45° to Wind	100	0	100
200	Facing Wind	66	0	100
	60° to Wind	75	0	100
	Closed End Facing Wind	4	0	100
400	Facing Wind	97	0	100
600	Facing Wind	43	0	100
800	Facing Wind	50	7	90
1100	Facing Wind	5	0	100
Check Barrel		0	50	0

Adult *Culex erraticus*, which formed a small percentage of the population and were not counted prior to this or the previous test, are somewhat more resistant than the adult *Anopheles*.

FIELD RESULTS III—DEPOSITION AND CONTROL OF LARVAE.—There are three main factors tending to reduce concentration and therefore vertical deposition as the aerosol cloud is carried further from the generator:

1. Progressive deposition of particles on the ground, trees and shrubbery so that less and less of the toxic material is airborne.
2. Dilution of the remaining airborne particles with air laterally, *i.e.*, the cloud fans out sideways as the wind carries it along over the ground.
3. Dilution of the remaining airborne particles with air vertically, *i.e.*, the top of the cloud gets higher and higher.

Deposition Measurements: Tests were made, when conditions permitted, of the variation in the amount of deposition

Table 10.—Results on natural adult mosquito population. Test I. August 24, 1944. (All counts made under sunlight.)

Tree Number (See Figure 1 for Position)	Before Test	After Test			
		12 Hours	2 Days	4 Days	6 Days
1	12–15A	1A	3A	0	2A
2	100A	1A	3A	1A, 3C	2A, 3C
3	15A	1C	1C	0	5A, 3C
4	10A	5A, 2C	6A	4A, 1C	6A, 2C
5	10–12A	2C		1A	3A, 3C
6	25–30A	0	0	0	1A, 1C
7	15A	3C		3C	
8	30A	1A		6A, 1C	8A, 1C
9	15A	2C		2A	
10	10A	0		1A	

Table 11.—Results on natural adult *Anopheles quadrimaculatus* population in tree holes. Test J. August 28, 1944. (All counts made under sunlight.)

Tree Number	Number of Mosquitoes			
	Before Test	20 Minutes after Test	4.5 Hours after Test	2.5 Days after Test
2	25A	2A, 1C	2C	6A
3	50A	15A	3C	5A
4	50A	2A, 3C	1A	
5	30A	13A	1C	
6	15A	1C	0	
7	25A	4A, 1C	0	
8	30A		0	
9	40A		1C	
10	30A		0	3A
11	40A		2A, 1C	6A, 4C
12	13A		0	
13	50A		1C	4A, 1C
14	30A		1C	
15	60A		1A	9A, 1C
16	30A		0	2A, 1C
17	10A		0	
18	15A		0	
19	20A		0	
20	17A		0	
Check Tree holes				
1[1]	40A	28A	15A	10A
21	50A		50A	20–30A
22	25–30A		30A	14A
23	25A		20–25A	10A

[1] Tree #1 was in the southwest corner of the test area and a few feet out of the aerosol. Other check tree holes were just upwind of the test area.

with distance from the generator and where possible this data was correlated with kill of larvae.

Method: Prior to the test, flat china plates, 420 sq. cm., and an oleophobic slide, were set out at measured distances down wind. *Calco Blue Na*, 2.5 or 5 per cent in the oil, was usually used as the tracer although two tests were made with *Calco Oil Red N-1700*. The use of this red dye was discontinued because of its tendency to decompose thermally.

The solution of dye in oil deposited on the plates during the test was washed off using xylene and the resulting solution bottled and labeled.

Standard solutions of the dye used were prepared so that 1 ml. of the standard contained 0.01 mg. dye and this concentration was again reduced if necessary.

A *Beaver-Klett* colorimeter was used. The lower cups were filled with xylene in each case, and the solutions placed in the upper cups. The dye solution was diluted to a known measured volume, with in-

Table 12.—Deposition Results of Tests K, B, and I.

Length of Front, Feet	Particle Diameter Microns	Wind Speed, Feet per Minute	Inversion	Wind	Distance, Feet	Deposition Micrograms Oil Solution per Cm^2	Particle Diameter Deposited Material, Microns
Test K, Dense Forest: June 7, 1944							
100	6	Outside: 560–750. At 275 ft.: Less than 10	Fair	Fairly steady but variable at end of test	25	3.6	Range
					50	2.2	4–20
					75	2.5	
					175	1.0	
					275	0.62	
					375	.50	
					475	.02	2–10
Test B, Light-Dense Forest: June 16, 1944							
							Mass av.
400	6–8	Outside: 0–120	Good	Variable over a 90° range	40	38	
					65	21	
					115	11.4	
					165	5.7	
					215	3.1	
					315	1.0	
					415	0.8	12–14
Test I, Light Forest: August 24, 1944							
							Mass av.
500	10–14	Less than 30 in forest	Poor-Fair	Variable	200	4.3	10–16
					400	1.9	10–14
					600	0.79	10–12
					800	.13	6–12
					1100	.15	10–12

tensity close to that of the standard, and the two compared, using standard colorimetric procedure.

The total amount of dye in milligrams per plate was determined, and from this the micrograms of oil-dye-DDT per cubic centimeter could be calculated.

The slides were examined under a microscope for particle size. In a good number of tests, plates and slides were washed out by rain and difficulties were encountered in slide examination because of the irregular spreading of the oil drop-

Winsche's results for various reasons. The wind speeds and directions in the field, for example, are, in general, variable so that comparison with figures based on a fixed wind velocity are difficult to make. Also the theoretical treated aerosol is completely homogeneous which is, of course, not true of a practical aerosol. The pertinent data summarized in table 13 however, suggests that the distances over which the particles are airborne may be much greater in dense forest than the distances indicated by the theoretical treat-

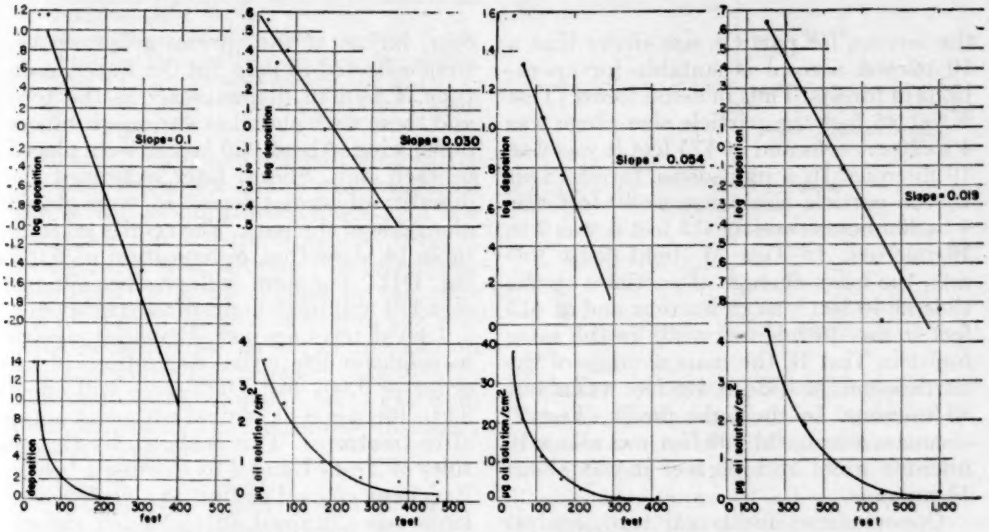

FIG. 2A.—Deposition in micrograms *vs* distance in feet. High pressure sprayer. One microgram equals 10^{-6} gram.
2B.—Deposition *vs* distance in dense forest. Test No. K.
2C.—Deposition *vs* distance in a light-dense forest. Test No. B.
2D.—Deposition *vs* distance in a light forest. Test No. I.

lets on the oleophobic surface caused by the emulsifier used in the emulsion preparation.

In several tests with larvae, dye was not used and in such cases mass concentration was determined from a microscopic mass count of the slide.

The results of deposition tests in three different types of forests are given in table 12 and plotted in figure 2. The logarithm of the deposition against the distance down wind is a straight line showing that the amount deposited is exponentially related to the down wind distance. The deposition of particles from aerosol clouds is treated theoretically by Winsche (1944) based upon Sells (1931) deposition studies. The deposition data do not permit a direct comparison with

ment. (No DDT was used in tests K, L, and M.)

The apparent inconsistency of results of Tests K and B is, of course, explained by the much lower wind velocity in the forest in the case of Test B.

Also involved in these questions are the relative degrees of inversion and the relative meaning of "dense" and "light" forests.

The deposition from a 2 micron aerosol (Test A) was found to be very light even in the dense forest with wind velocities of about 0.05 mi. per hr. The deposition obtained in this test was of the order of 10^{-4} ug oil solution per square centimeter between 150 and 700 feet down wind.

Examination of microscope slides, placed at various distances down wind into

Table 13.—Comparison of experimental and theoretical deposition.

		Field Results			Theoretical Treatment		
Terrain	Test	Slope	Particle Diameter	Wind Velocity Miles per hr.	Slope	Particle Diameter	Wind Velocity Miles per hr.
Dense Forest	K	0.030	6	outside forest 6–8; 275 ft. inside forest 0.1	0.083 0.5	8 8	1 0.1
Light Forest	I	0.019	10–14	inside forest 0.05–0.3	0.015	8	0.1
Light Dense Forest	B	0.054	6–8	outside forest <0.05–<1.5			

the forests, for particle size shows that a 10 micron aerosol is suitable for operations in forests. Thus in dense forest (Test K) at 25 feet the particle size range was 4 to 20 microns and at 475 feet it was 2 to 10 microns. In a light-dense forest (Test L) the particle size range at 40 feet was 4 to 26 microns and at 415 feet it was 2 to 10 microns. In Test M (light-dense forest), the mass average of particles on the slide at 40 feet was 20 microns and at 415 feet it was 16 microns while in the same forest in Test B, the mass average of the particles on the slide at 415 feet was about 13 microns. In the light forest (Test I) the mass average at 200 feet was about 13 microns while at 1100 feet it was about 11 microns.

Opportunities for larval tests against salt marsh species (*Aëdes sollicitans* and *A. taeniorhynchus*) were not abundant. Thus none of the areas treated in the Cocoa experimental grounds, including Sykes Creek marshes showed natural breeding during the periods in which the field tests were made. In two tests, however, larvae of the species given above, were collected in pans (of the water basin type, 1 foot in diameter across the top) and these were placed at various distances down wind. About 200 larvae were placed in each pan. Slides, later examined for quantity of aerosol deposited, were placed alongside of the pans. The results given in table 14 show that a deposition of 0.002 lbs. DDT per acre will produce 50 per cent kill within 18 hours after treatment.

Larval tests against *Anopheles quadrimaculatus* indicate that depositions of the order of 0.001 lbs. DDT/acre will effect 95 to 100 per cent control within 12 hours after treatment. This is shown by the results of Tests I and J as discussed below. Excellent control against *A. quadrimaculatus* was obtained in the lotus swamp area in Buckeye Swamp (Test O).

Test O (August 21, 1944). This was a test against the natural population of *Anopheles quadrimaculatus* larvae in the heavily vegetated (lotus covered) Buckeye Swamp. During the two days prior to the test the swamp waters were system-

Table 14.—Results against larvae of *Aëdes sollicitans* and *A. taeniorhynchus*. 200 larvae per pan.

Test No.	Terrain	Down Wind Distance, Feet	Deposit Lbs. DDT per Acre	Per Cent Mortality Hours After Test 1.5	4	12	18
N	Dense Forest	25	0.084		100	100	
		125	.049		98	100	
C	Light-Dense Forest	225	0.064	100			100
		460	.025*	affected			90
		600	.0035				
		840	.0019	affected			50
Checks: Both tests:				0	0	0	0

* Extrapolated.

atically dipped by 5 observers and a uniform population of *A. quadrimaculatus* larvae established at a rate of 1–2 per dip; *C. erraticus* averaged 1–5 per dip. The swamp was also systematically examined after the test.

Operative conditions

Length of front: 1000 feet, A to C on figure 3
Wind speed: Variable—100 feet per minute
Inversion: Very good to good
Time of test: 05:50 to 07:50
Particle size: 12 to 14 micron diameter
Emulsion used: 50 parts oil–50 parts water by volume; DDT content being 10 per cent of the oil by weight
Dosage: 30 gallons of emulsion per 1000 feet of front, but the wind direction was quite variable. The wind was variable easterly and southerly; occasional northerly and north-easterly winds were present.

Results: Eight and one-half hours after the test, search for larvae was conducted across the swamp directly north of the generator run and from point C (Fig. 3) to 2500 feet west. During this search one *Anopheles quadrimaculatus* larvae was found. Twenty-four hours later, the systematic search for larvae in the swamp was continued and extended. The following numbers of *A. quadrimaculatus* were obtained over the indicated distances covered (Fig. 3):

From Point C to 2300 feet west	3
From 2300 west to 2600 feet west	3
From 2360 west to 2800 feet west	1
From 2800 west to 3200 feet west	0

(Note: These are the numbers found; not the average number per dip)

This constitutes practically 100 per cent control of the natural population of *Anopheles* larvae over the area covered. Also a pool of larvae located about 3000 feet west-northwest of point D (Fig. 3) was found free of larvae. Previously (up to the day before the test) this pool was a very good source of *Anopheles* larvae.

Seven days later, a survey of the treated swamp showed only first and second instar larvae; the number being 0 to 8 per dip. This indicates a residual toxicity to larvae of from 4 to 5 days duration.

Excellent control was obtained against *Culex erraticus* in the lagoon between point C (Fig. 3) to 1800 feet west.

Test I (Description of terrain and operational conditions previously given). During this test, *Anopheles quadrimaculatus* larvae in pans were located at each of the posted stations. The results given in Table 15 show that practically 100 per cent control was obtained against the larvae up to a minimum of the 1100–foot station.

Test J (Description of terrain and operational conditions previously given). The results of this test indicate that depositions of the order of 0.0001 lb. DDT per acre or less, effect little, if any, control of larvae of *Anopheles quadrimaculatus*.

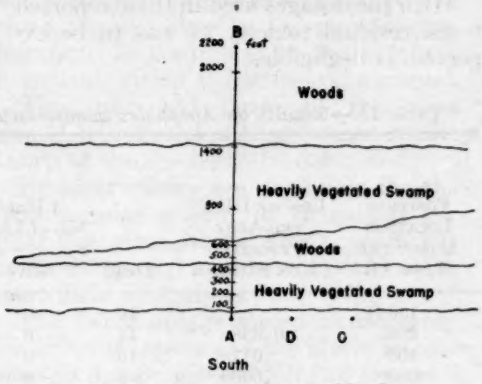

FIG. 3.—Area map for test No. O.

FIELD RESULTS IV—CONTROL OF PUPAE.—With dosages used in these field tests for control of adults and larvae control of pupae is negligible. Thus in Test C (Table 14), pupae at all positions were only slightly, if at all, affected. It is interesting to note however, that several pupae at position No. 4 died and about 10 of the emerging adults drowned before being able to "take off." All emerging adults in the control pans were successful in their "take off." In Test I (Table 15) two pupae, in the larva pan at the 200-foot position, were definitely sick 12 hours after the test. But 24 hours later one was dead and the other successfully emerged.

RESIDUAL AND REPELLENT EFFECTS.—The campaign against the mosquito must be confined, by necessity, to the clearing of specific areas. After a given area has been cleared, there will be a more or less rapid migration of mosquitoes from the outlying untreated areas into the cleared section. The ideal treatment would be one which kills not only all adults in the treated area at the time of treatment but also those which subsequently migrate into that area. This means rendering the area treated more or less permanently

toxic by deposition of sufficient quantities of aerosol upon the ground, logs, foliage, etc.

The toxic material so deposited can act only by contact with the mosquito when it lights upon a surface on which droplets of the oil solution of the toxic agent have been deposited. The vapor pressure of DDT is so low that there can be no kill on the wing from vapor.

With the dosages used in these reported tests, residual toxicity as was to be expected, is negligible.

posited are too small to render the treated area toxic to infiltrating mosquitoes. The absence of any repellent effect was demonstrated in the following experiment:

After the 4-hour check period in Test I the four barrels, at positions 100, 200, 400, and 600 feet wherein 100 per cent mortality was obtained (Table 9) were set out at 03:00 hrs. near Blackwell Swamp (the screens, of course, were removed from the barrels). At 10:15 hrs. the barrels were inspected and the following counts made:

Table 15.—Results on *Anopheles quadrimaculatus* larvae in pans. Test I. August 24, 1944.

Position Location Along the Line AB	Lbs. of DDT per Acre Deposited on Slide	Hours After Test: 4 Hours No. of Larvae			12 Hours No. of Larvae		
		Dead	Alive	Mortality	Dead	Alive	Mortality
100 ft.		10	0	100%			100%
200	0.038	15	0	100			100
400	.017	10	0	100			100
600	.0069	8	0	100			100
800	.0011	13[1]	0	100			100
1100	.0013	22	2[2]	90	23	1[3]	95
Check		0	11	0			

[1] One Columbiae larva in pan dead.
[2] One of these two is *Uranotaenia sapphirina*.
[3] Apparently dying.

The only test made for residue effect was discussed under Field Results I (Test B) and also under Deposition and Larval Control.

An area infested with salt marsh mosquito remains clear for only several hours, unless the area treated is very large, or the dosage so large that enough material is deposited (1 lb. per acre of DDT) to kill infiltrating mosquitoes. On the other hand, an area cleared of *Anopheles quadrimaculatus* may remain free for several days (Tests I and J) because of their comparatively slow rate of infiltration. The duration of this protective period depends upon the extent of the treated area and probably upon the proximity of breeding holes to the treated area as well as other factors.

It is to be emphasized that the protective periods obtained in these two tests against *Anopheles quadrimaculatus* was not due to a deposited toxic residue nor to any "repellent effect" of the deposited aerosol. In the first case, the amounts de-

Barrel from Position	*Number of Mosquitoes Resting*
100 ft.	50
200	100+
400	100+
600	300+

Hence residual or repellent effects are negligible.

Effect of DDT Aerosol on Personnel.—The four Columbia University field workers who conducted the experiments in Florida and Alabama, May 1 to August 28, were carefully examined by the U. S. Public Health Service at Bethesda, Md., before and after this period. Reports show no ill effects.

Negative Tests.—Three tests were cancelled by mechanical difficulties of such a nature that they could be eliminated from a professionally designed generator.

Seven tests were cancelled by highly variable winds or winds for which no field preparations could be made. The method of operation is, however, so efficient, compared to standard spray methods of

control, that even with delays brought about by adverse meteorological conditions, the number of acres covered per man-hour will be greater. Of course, no method which aspires to cover large areas in a single treatment will be completely independent of meteorological conditions.

One test was cancelled because of the absence of a sufficient number of adult mosquitoes. Another test was rained out because the personnel and equipment was not sufficient to warrant operation under such conditions; however, ordinary rains do not interfere with operations. Another test was cancelled because the generator carrier, an ordinary rowboat, developed a serious leak.

CONCLUSIONS.—Aerosols formed by dispersing oil containing DDT can be effectively employed in the field for mosquito control operations. Aerosol treatment will kill adult *Anopheles* in tree holes, hollow logs and other natural resting places. The method should prove applicable to general insect control.

A dosage of 15 gallons, of 50 parts oil–50 parts water emulsion, by volume, and containing an amount of DDT equal to 10 per cent of the weight of the oil, per 1000 feet of front will give effective adult control up to about a mile down wind in open country under favorable meterological conditions and to about 1000 feet in forested areas. In recommending a fixed dosage of 15 gallons per 1000 feet, it was assumed that for practical purposes the extent of control would be independent of wind velocity. This was confirmed later in wind tunnel experiments, to be reported separately, when the particle diameter was of the order employed in these tests.

This dosage will produce practical larval control up to about 2000 feet in open country and from 500 to 1000 feet in forested areas.

For control of adults, a 10-micron diameter aerosol can be used regardless of wind velocity and terrain. For control of larvae, however, the particle size should be increased for winds of 3 or greater miles per hour (except, of course, for control in forested areas where 10 microns must be used to obtain penetration).

Operations should be carried out under meteorological conditions wherein the cloud remains close to the ground since insects to be controlled are to be found, in general, within 15 feet from the ground.

The time and mode of treatment should be selected with reference to the habits of the species to be controlled.

Residual effects are negligible for the recommended output of 15 gallons per 1000 feet given above but a significant protective period may be obtainable with short flight mosquitoes.

The lethal dosage varies considerably for different insects and the above recommended dosage will *not* kill "all insects." The recommended dosage did not harm the fish of Sykes Creek, Florida.

A local deposition of the order of 0.002 lb. DDT per acre will produce 50 per cent kill on the larvae of *Aëdes sollicitans* and *Aëdes taeniorhynchus* within 18 hours after treatment and depositions of the order of 0.001 lb. DDT per acre will effect 95 to 100 per cent control of larvae of *Anopheles quadrimaculatus* within 12 hours after treatment.

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Particle Size of Insecticides and Its Relation to Application, Distribution, and Deposit

S. F. Potts, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Recent developments in the application of insecticides in the form of smokes, liquefied-gas aerosols, and finely atomized sprays, with equipment operated from the ground and from aircraft, have attracted attention to the significance of particle or droplet size as a factor in determining deposit, distribution, and effectiveness of dusts and concentrated sprays. Under field conditions extremely minute individual particles of finely ground dusts, insecticidal smokes, finely atomized aerosols, and concentrated sprays are not deposited on the surface of plants, insects, and other objects. Apparently such objects are surrounded by a film, or field of resistance, the nature of which is not known and through which minute particles cannot penetrate. An electric field around such objects may possibly cause a repulsion of minute particles. Microclimatic conditions caused by differences in temperature, humidity, and weight of air near such objects produce air currents which carry away minute particles. Deposit is particularly light on warm, sunny days, and often there is a difference in temperature of as much as 10 Fahrenheit degrees between the sunny and shady sides of a leaf. Less deposit has been noted on the underside of cup-shaped or crimped leaves than on the upper surface.

Larger individual particles, whether dry or liquid, as well as groups or agglomerates of small dust particles, are heavy enough to penetrate the film of resistance and make contact with the surface of leaves, insects, and other objects.

Dusts.—A series of studies conducted from 1926 to 1935 brought out the following conclusions concerning dusts:

Small individual dust particles do not give a good deposit. Dust clouds consist of mixtures of individual particles and groups, which may be composed of 25 to 300 individual particles (Potts 1940). Such groups of dust particles may settle on a surface, but do not adhere well. After dust is expelled from a blower, these groups of particles do not tend to break up nor do the individual particles in the cloud tend to coalesce.

Dust particles of heavy substances, such as barite, deposit somewhat better than do particles of light materials, such as derris, although from the standpoint of deposit the weight of the individual particles of a material is not so important as the presence of agglomerates in the dust cloud.

Proportionately more dust is deposited from a cloud of heavy dust expelled from a blower at a low velocity than from a cloud of light dust expelled at a high velocity and with a large volume of air.

Dust applied at a high velocity penetrates the resistant film around objects near the blower and deposits on them; however, at several feet from the blower the effect of high initial velocity is lost. This explains, in part, why ground equipment may never be very effective in dusting trees.

The fineness of a dust, as indicated on the package or container, is not a criterion of its depositing qualities. The following insecticides are listed in descending order of the proportion of dust deposited on the foliage: Sulfur, lead arsenate, derris and cube, pyrethrum, and cryolite. Sulfur particles are fairly large, as compared with those of the other materials. Lead arsenate particles are heavy and very fine (mostly less than 2 microns in diameter), but when applied this material forms groups of particles. Derris, cube, and pyrethrum dust particles are light and coarse. Cryolite dust has a greater tendency than most materials have to break up into individual particles upon application. It gives a lighter deposit than lead arsenate, but the deposit can be considerably increased by adding 10 or more parts of pyrophyllite to each part of cryolite.

Dust swaths applied by aircraft are often several hundred feet wide but their effective width is seldom more than 40 to 60 feet, the effectiveness being confined mostly to that part of the swath where a deposit of agglomerates, or particle groups, exists.

The failure to control insects with dusts is due to light deposit and poor adher-

ence, rather than to small quantity of material or small number of particles applied. Even when a dust having a particle diameter of 0.5 to 2 microns is applied at the rate of 1 pound per acre, although thousands of particles per square millimeter of surface might be available, insect control might not be obtained.

AIR-MIXED, OIL-COATED DUSTS.—When a cloud of finely atomized dust is mixed with a cloud of finely atomized oil, in the absence of pressure or vacuum, there is little tendency for the oil particles to coalesce with the dust particles and only a small percentage of the dust particles are coated with oil. It seems possible that at least the smaller particles may actually repel each other. On the other hand, when an oil or other liquid is atomized by the force of a stream of compressed air (15 pounds pressure or more) which contains the dust, a fairly good coating is obtained. A considerable amount of dust can be coated if the liquid is finely atomized with high-velocity (150 to 300 m.p.h.) air from a blower. The coated particles coalesce into groups and adhere to foliage better than do ordinary uncoated dust particles

CONCENTRATED SPRAYS.—The failure of dusts to deposit and adhere satisfactorily on foliage has led to the development of highly concentrated insecticidal sprays and the application of these concentrates as finely atomized mists. This method permits coverage with a lower volume per acre. Although fine atomization is necessary to obtain adequate distribution with low rates of application, the droplets must be large enough to give a satisfactory deposit on foliage and insects. There is little deposit of droplets less than 20 microns in diameter; in fact, very few are deposited unless their diameter exceeds 30 microns. The initial deposit of finely atomized sprays is several times as great as that of dusts. The loss of deposit caused by rain and wind makes the difference between dusts and atomized sprays even more pronounced in favor of the sprays.

FACTORS AFFECTING PARTICLE OR DROPLET SIZE.—The numbers of droplets of given size that would be deposited per square millimeter and per square inch (645 square millimeters) by the distribution of 1 gallon of spray (3,785,000,000,000,000 cubic microns) uniformly over a surface of 1 acre are shown in table 1. A droplet diameter of 40 to 70 microns would result in a deposit of 17,931 to 3,354 droplets per square inch, and a diameter of 80 to 100 microns, a deposit of 2,157 to 1164 droplets per square inch. The writer believes that for the application of concentrates sprays with ground equipment the optimum range for diameter of droplets should be about 30 to 80 microns and for aerial application about 70 to 100 microns, both depending on the density and type of the insecticide, the volatility of the carrier, the plant growth, the kind of insect, the type of distributing device, and the atmospheric conditions. Under certain circumstances, which are discussed later in this paper, the droplet size for aerial application should be considerably greater. It will be seen in table 1 that a slight change in diameter changes the volume and number of droplets mate-

Table 1.—Size and number of droplets deposited per unit area by distributing 1 gallon of liquid uniformly over a surface of 1 acre.[1]

ACTUAL DIAMETER (MICRONS)	VOLUME (CUBIC MICRONS)	NUMBER OF DROPLETS PER SQUARE MILLIMETER	NUMBER OF DROPLETS PER SQUARE INCH
1	0.52	1,780,125	—
2	4.2	222,516	—
3	14.18	65,930	—
4	33.6	27,814	—
5	65.6	14,242	—
6	113.4	8,241	—
7	180	5,197	—
8	269	3,476	—
10	525	1,780	1,148,100
12	907	1,030	—
13.5	1,289	725	—
15	1,772	527	—
17.5	2,814	332	—
18	3,062	305	—
20	4,200	222	143,190
24	7,257	129	—
25	7,442	125	80,625
30	14,175	66	42,570
35	22,507	41.5	26,767
40	33,600	27.8	17,931
45	47,838	19.5	12,577
50	65,520	14.3	9,224
55	87,343	10.6	6,837
60	113,400	8.2	5,289
70	180,007	5.2	3,354
80	268,800	3.5	2,157
90	382,725	2.44	1,574
100	525,000	1.78	1,164
110	699,000	1.33	856
120	907,000	1.03	664
130	1,153,000	.81	530
140	1,440,000	.65	425
150	1,771,000	.53	347
160	2,150,000	.43	277
170	2,579,000	.36	232
180	3,061,000	.30	194
190	3,600,000	.26	168
200	4,200,000	.22	142
220	5,590,000	.17	111
240	7,257,000	.12	78
260	9,227,000	.10	65
280	11,528,000	.08	52
300	14,175,000	.066	43
400	—	.028	18
500	—	.014	9
1,000	—	.0018	1.1

[1] Equivalent to 934,568 cubic microns of liquid per square millimeter.

rially. For example, when the diameter is 20 microns, there are about 8 times as many droplets as at 40 microns diameter; nearly 16 times as many at 40 microns diameter as at 100 microns; and about 125 times as many at 100 microns diameter as at 500 microns. At 50 microns diameter there are about as many droplets in 1 gallon of mixture as in 143 gallons when the diameter is 260 microns. In any spray pattern there are proportionately a great many more small droplets than large ones, but the greater volume of spray is in the larger droplets.

When slowly volatile or nonvolatile oils are finely atomized, the droplets on an object tend to coalesce to form a continuous film over the exposed surface. When the oil is spread evenly, approximately 1 gallon per acre of leaf surface is ordinarily required to form a continuous film. Better control of spider mites and such insects as thrips, aphids, and snout beetles is obtained with droplets of smaller size than are needed for large insects and gross feeders. Many first-instar aphids are only 0.6 square millimeter in size. A white pine weevil adult makes a 0.8-millimeter hole in the bark in the process of feeding, and 1,000 or more droplets of lead arsenate concentrate are required per square inch of bark to effect good control, because female weevils must be killed quickly before they lay eggs. For many gross feeders a much smaller number of droplets having a diameter of 150 to 300 microns would be adequate.

Wetting agents in sprays containing water reduce the droplet size 30 to 50 per cent. Droplet size is an important factor to be considered in studies of foliage injury. The danger of injury is lessened with a decrease in droplet size and in the quantity of phytotoxic ingredients applied per acre. If the wetting agent is phytotoxic, it is better to use as little of it as possible and to reduce the droplet size by mechanical means.

The area of foliage per acre to be covered governs to a considerable extent the volume of spray required. The amount, however, is also dependent on the degree of atomization produced by the distributing apparatus. Consequently, the finer the atomization the less spray will be required to cover a given area of foliage, except that if the atomization is too fine there will be very little deposit. With less volume and finer atomization it is necessary to increase the concentration of the spray mixture to obtain adequate dosage.

In concentrates containing water the droplets tend to flatten out when they strike the surface of a leaf. The increase in diameter caused by spreading ranges from very little to approximately 300 per cent, depending on the size of the droplet, the type and amount of wetting agent used, and the extent to which the particles dry out before reaching the foliage. Oil droplets may increase to from 10 to 15 times their original diameters, depending on the type of leaf surface, the droplet size, and the viscosity of the oil. Spreading is even greater on glass plates than on leaves.

APPLICATION OF SPRAYS WITH GROUND EQUIPMENT.—Other things being equal, the distance over which blowers can drive a cloud of finely atomized spray mist is directly related to particle size. In 1940, at Gulfport, Miss., a 5-horse power blower with atomizing nozzles set in the dust-outlet tube was used to apply a fine spray of droplets 60 to 80 microns in diameter and a coarse spray with droplets 300 to 400 microns in diameter. The finer spray was driven a horizontal distance of about 150 feet, whereas the coarser spray could be driven only 20 to 40 feet. The finer spray could have been driven vertically a distance of 40 feet with this blower. With specially designed equipment it would seem possible to drive finely atomized spray to considerably greater heights where there is no wind movement.

Under suitable conditions the blower used at Gulfport was capable of drifting a cloud of dust horizontally about 250 feet, but beyond the first 20 feet there would not have been a deposit adequate to control insects. The droplets in the fine spray mist driven by this blower, however, were deposited for a distance of fully 100 feet in sufficient quantities to give good control of insects. Recent experiments indicate that a machine of this design could be used effectively for treatment of certain broadcast crops by covering 100-foot strips, thus avoiding considerable crop damage that might be caused by usual methods of treatment.

AERIAL APPLICATION OF SPRAYS.—In the application of liquid sprays from aircraft the size of droplets greatly affects

the width of the swath covered, the distance the spray cloud will drift, the settling rate, the penetration of the ground cover, and other factors. Measurements of droplet size and width of swath were made at Whitesbog, N. J., in 1937, when an autogiro was used for applying two concentrated sprays. In these tests lead arsenate spray, with and without a wetting agent, and pyrethrum extract in kerosene were used. The spray mixtures were atomized by being spun off from rotating disks. They were applied at the rate of 3 gallons per acre.

When released 20 feet above the ground or 20 feet above the treetops, the lead arsenate spray that contained no wetting agent covered a swath 75 feet wide. The average droplet size was calculated by dividing the total deposit per given area, as found by chemical analyses, by the number of droplets. There were 215 droplets per square inch on plates placed on flat ground and 43 droplets per square inch on foliage in a sprayed woodland. The diameter of the droplets averaged approximately 240 microns. The addition of a wetting agent reduced the droplet diameter to about 200 microns and increased the width of the treated swath to 90 feet. With the pyrethrum extract-kerosene spray a swath about 100 feet wide was treated, the droplets being somewhat smaller and lighter than those in the lead arsenate spray mixture.

In aerial application the use of a larger droplet is necessitated by wind, upward air currents due to heat radiation, layers of heavy, humid air above the treetops, and small irregular areas and rugged terrain. Low flying over large areas of level terrain makes practicable the use of smaller droplets, and therefore lower gallonage, at lower costs. For low flying over crops it might be practicable to use average droplet sizes as small as 60 to 70 microns. Except where it is necessary to kill insects under heavy canopy, larger droplets would be preferable for the treatment of forested areas.

Droplets of high specific gravity (1.3 to 1.6) can be deposited in smaller sizes than those of lower specific gravity (0.8 to 1.0). For droplets with a specific gravity of 1.0, and of various diameters, the time required to fall 50 feet, in ordinary still air at a temperature of 23° C., is as follows:

Diameter (Microns)	Time
200	13 seconds
100	51 seconds
80	1.3 minutes
50	3.4 minutes
40	5.2 minutes
20	21.0 minutes
10	1.4 hours
5	5.5 hours
1	5.0 days

Upward or downward air currents will change the rate of rise or fall, but wind velocity does not alter it (Miller 1935, p. 160). The rate of fall of droplets of different sizes was computed by Stoke's law. Other things being equal, the smaller the droplets and the longer they float in the air the greater the evaporation and drift. Temperature, humidity, wind velocity, and chemical characteristics also affect evaporation and drying of the particles. Considerable evaporation reduces the size of the drops and makes them fall more slowly and drift farther. Some increase in size and weight of falling particles has been obtained by the addition of *Yumidol* (a hygroscopic hexahydric alcohol). Phosphorus pentoxide, magnesium chloride, and calcium chloride particles greatly increase in size and weight as they float in the air, but when mixed with an insecticide these chemicals cause injury to some kinds of foliage.

The distances that a droplet 100 microns in diameter and having a specific gravity of 1.0 would drift while falling 50 feet in air moving parallel to the ground are as follows:

Miles per Hour	Feet
0.25	22
0.5	45
1	87
2	175
3	265
4	348
5	435
10	765

A droplet 200 microns in diameter should drift practically one-fourth and a 10-micron droplet about four times the distances given.

Smoke Aerosols.—In 1930 and 1931 field tests were made with smokes containing arsenicals, oil, rotenone, pyrethrum, and nicotine, Practically no particles in the smoke aerosol cloud were deposited, nor was any appreciable mortality of insects obtained. In some cases

the insecticide broke down on account of heat. Smoke particles range from 0.3 to 2 microns in diameter and are not smaller than many particles of lead arsenate and calcium arsenate dusts.[1] Smokes differ from dusts, however, in that the particles in a smoke cloud move as individual, unattached particles, whereas in a dust cloud the particles often occur in groups. Individual dust particles less than 35 microns in diameter cannot be seen on slides or on foliage with the unaided eye, but groups of dust particles can readily be seen without magnification.

LIQUEFIED-GAS AEROSOLS.—In liquefied-gas aerosols the gas, such as *Freon-12* (dichlorodifluoromethane) or methyl chloride, comprises from 40 to 90 per cent of the aerosol solution. When released, the liquefied gas volatilizes quickly and the droplets immediately become smaller. Any further reduction in droplet size depends on the solvent and the volatile ingredients in the solution; therefore the droplet diameter could be the same as in mechanically atomized sprays containing the same solvent.

For application of liquids very small droplets, 4 to 40 microns in diameter, can be obtained by atomizing either with liquefied gas or with mechanical atomizing equipment. Suspensions of solid particles, such as cryolite and lead arsenate, can be applied with mechanical atomizing equipment, but not with liquefied gas. To deposit on the foliage the same number of droplets of given size by liquefied gas as by the mechanical method, it is necessary to apply a larger volume of liquid, the quantity depending on the proportion of liquefied gas in the solution.

SUMMARY.—Particle size is an important factor in determining deposit, distribution, and effectiveness of dusts and concentrated sprays. A field of resistance surrounds all objects, including plants and insects, and repels most individual dust particles of small size, as well as droplets smaller than approximately 30 microns in diameter.

Ordinary dust clouds consist of a mixture of individual particles and agglomerates of many particles attached together. If the particles are small, the deposit on insects and plants consists almost entirely of agglomerates.

Dust particles may be coated in the air by small droplets of oil, if the mixing takes place either in a vacuum or under pressure.

Fine atomization is necessary to obtain adequate distribution with low gallonage, but the droplets must be large enough to deposit on foliage and insects. Apparently for ground application most of the spray should be in droplets 30 to 80 microns in diameter. For aerial application most of the droplets should be 70 to 100 microns in diameter if the areas are large and flat, and as large as 100 to 300 microns for the control of certain forest insects on rugged terrain.

The number of droplets of given size that would be deposited per unit area per gallon of liquid distributed on acre of surface is presented.

Other factors affecting particle or droplet size are type of distributing device, concentration, density, and type of insecticide, rate of volatilizaton of the ingredients, distance to which the particles must be drifted, wind and other meteorological factors, volume and compactness of foliage, and settling rate.

[1] During the last several years members of the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine, notably E. L. Gooden, L. D. Goodhue, C. M. Smith, and R. H. Carter, have done a great deal of work in determining the size of insecticidal-dust particles.

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Dr. Richard B. Eads has sent in a new address—College Station, Texas. Just what Dr. Eads present connection is, was not indicated in the communication.

Protection of Mohair Fleeces in Storage from Moths by Dipping Goats before Shearing[1]

E. A. Back, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The problem of treating animal fibers, especially wool and mohair, so that they will remain resistant to insect attack has been given much attention by experimenters during the past 25 years. The chief interest of the experimenter, of the manufacturer, and of the public, has been in making clothing, or the yarns from which the fabrics are woven or knit, moth resistant. Mothproofing treatments have been given, either as a part of the manufacturing process or by public service firms, to the finished fabric, such as carpets, blankets, upholstery, and clothing.

Practically nothing has been done to render animal fibers moth resistant during that period between shearing and the manufacturing processes. During this storage period the wool or mohair is subject to moth attack, especially by the clothes moths *Tineola bisselliella* (Hum.), *Tinea pellionella* L., and more rarely by *Tineola columbariella* (Wocke). In normal times most American wool and mohair fleeces are consumed in trade channels in about 2 years after shearing and, while moth damage often occurs, it is not considered as excessive. However, every entomologist having wide experience with the calls for assistance from farmers, wool dealers, and manufacturers, who must hold stocks of animal fibers, realizes that the losses caused by insects during the prefabrication stage are persistent and sometimes ruinous. Government ownership of wool and mohair during the war years has emphasized the benefits that would be derived if some treatment could be given fleeces to keep them reasonably safe from moth attack from the time they are sheared from the animal until they enter the manufacturing process.

It does not seem practical to treat fleeces after they are removed from the animal and before manufacture. They are crammed into burlap sacks, or baled, and if they get wet it is an expensive operation to dry them out. Fumigation of storage warehouses has been resorted to, along with the use of naphthalene and paradichlorobenzene. Contact sprays have given only temporary relief and do not get at the seat of the trouble. Storage conditions often make ordinary control ineffective.

In connection with the Bureau of Entomology and Plant Quarantine's treatment of Angora goats in Texas by dipping to control lice and ticks, several dips containing DDT were used with very promising results by Henry E. Parish. Animals dipped on March 27, August 26, and August 31, 1944 were sheared in each case 4 days after dipping. The fleeces were sent to Washington for testing to determine the resistance of the mohair to moth attack.

Fleeces from animals dipped in three solutions were forwarded for testing. Dip No. 1 contained DDT 20 per cent, diethyl phthalate 35 per cent, *Triton 720* (sodium salt of an aralkyl polyether sulfonate) 20 per cent, and water 25 per cent. Dip No. 2 contained 1 part of DDT and 5 parts of soluble pine oil (Navy Specification C.S. 69-38). Both these dips were diluted with water so that the solution as used on the animals contained 0.2 per cent of DDT. The third dip was made by mixing 10 pounds of wettable sulfur with 100 gallons of water. As checks, mohair sheared from untreated animals and mohair sheared and scoured about 10 years ago was used.

Forty tests of mohair sheared from animals dipped March 27 and sheared April 1, 1944, were run between July 20 and September 15, 1944. During the progress of these tests the accumulation of frass was so meager that it was considered negligible and was unfortunately not weighed. These tests, however, were repeated during the period from September 22 to December 31, 1944, and February 3 to March 7, 1945, with results recorded in table 1. For test insects the black carpet beetle, *Attagenus piceus* (Oliv.), and the furniture carpet beetle, *Anthrenus vorax* Waterh., were used.[2]

[1] From Eastern Branch Program, New York, 1945.

[2] Testing laboratories have elected to use *Attagenus piceus* as the most satisfactory insect for determining "moth resistance." Carpet beetles are easily handled and *A. piceus* is readily available. Fabric resistant to carpet beetles is resistant to clothes moths, although the opposite may not be true. While *Tineola bisselliella* (Hum.) and *Tinea pellionella* L. are the most trouble-

Table 1.—Resistance to insect attack of mohair fleeces from animals variously treated, as indicated by the weight of the frass; 25 insects used in each test.

Treatment	Number of Tests per Species	Average Frass Weight, in Milligrams	
		Attagenus piceus	*Anthrenus vorax*
Sept. 22 to Dec. 31, 1944			
DDT dip No. 1	20	3.7	7.1[1]
DDT dip No. 2	10	8.4	4.1[2]
Check, scoured	6	109.2	206.3
Feb. 3 to March 7, 1945			
DDT dip No. 1	20	3.1	1.6
DDT dip No. 2	15	3.3	4.8
DDT dip No. 2	20	4.6	3.9
Sulfur dip	20	89.2	85.4
Check, as sheared	10	88.9	91.1
Check, scoured	5	104.5	101.3

[1] Average based on 3 tests.
[2] Average based on 2 tests.

There are various methods of evaluating the results of tests to determine moth resistance of animal fibers. In table 1 the weight of the frass has been chosen to indicate this resistance. A study of many tests of fabrics treated with mothproofing solutions has resulted in the belief that when less than 11 to 13 mg. of frass accumulates during a petri-dish test using 25 insects the resistance imparted to the material is excellent. The average weight of frass per test of mohair from animals dipped in a solution containing DDT ranged from 3.1 to 8.4 mg. for *Attagenus piceus* and from 1.6 to 7.1 mg. for *Anthrenus vorax*—thus confirming the conclusions drawn from visual examination, that the protection imparted was excellent. Dipping the goats in the sulfur solution appeared to have no value in imparting moth resistance, since the 89.2 mg. of frass for *A. piceus* and 85.4 mg. for *A. vorax* approximate the frass weights in tests of untreated mohair of 88.9 mg. for *A. piceus* and 91.1 mg. for *A. vorax*.

The protection from clothes moths and carpet beetles offered mohair sheared from animals dipped in a solution of DDT is further emphasized by a study of the reaction of the 25 larvae to the treatment of the mohair. The data in table 2 cover the period February 3 to March 7, 1945, when both the black carpet beetle and the furniture carpet beetle are at the point of transforming from the larval to the adult stage. For this reason this is not ordinarily a good time of the year to run tests with these insects. But these particular tests have been chosen because, although

Table 2.—Average number of beetles in each stage in mohair of treated animals at end of test period February 3 to March 7, 1945; 25 insects used in each test.

Treatment	Number of Tests	*Attagenus piceus*					*Anthrenus vorax*				
		Larvae			Pupae	Adults	Larvae			Pupae	Adults
		Alive	Dead	Cast skins			Alive	Dead	Cast skins		
Check, as sheared	10	19.0[1]	0.0	[2]	2.2	3.8	5.4	2.4	18.1	9.6	7.6
Check, scoured	5	—	—	[2]	—	—	5.2	1.4	17.2	11.6	6.8
DDT dip No. 1	20	22.4[3]	2.25	6.15	0.15	0.2	5.8[3]	15.1	12.5	2.0	2.1
DDT dip No. 2	20	24.25[3]	0.25	13.45	0.15	0.35	10.4[3]	5.9	23.7	6.0	2.7
Sulfur dip	20	16.45[4]	0.5	[2]	3.35	4.7	5.65[4]	1.4	21.5	11.9	6.05

[1] Average of 5 tests.
[2] Cast skins too badly chewed for counting.
[3] Larvae abnormal.
[4] Larvae normal.

some pests of mohair and wool clips in storage in this country and are primary pests of fabrics woven from them, it is probably true that *A. piceus* and *Anthrenus vorax* can be even more destructive to knitted and woven fabrics. For this reason carpet beetles must be included in claims for "moth resistance." The word "moth" in the understanding of the public includes both carpet beetles and clothes moths, and animal fibers treated to render them "moth proof" or "moth resistant" should be treated so that they are resistant to carpet beetles as well as clothes moths. "Moth resistance" in this paper, and very generally in discussions of mothproofing treatments, includes resistance to both clothes moths and carpet beetles.

more larvae were alive at the end of the test period when confined with DDT-treated mohair than when confined with mohair treated with the sulfur dip or the check material, the number that transformed to pupae and adults was greatly reduced. Furthermore, the living larvae at the end of the month's test period were ab-

normal, being stunted and discolored and often determined as alive with some difficulty, and the pupae and adults were usually dead. No maturing adults laid eggs, they seemingly being incapable of reproducing themselves. In striking contrast, the insects confined with the check and sulfur-treated mohair were normal in every respect, large, robust, and very active. In no test of mohair from animals dipped in a DDT solution has any larva of either species remained alive for months, as have the larvae confined with untreated material.

Although fleeces from animals treated with dips No. 1 or 2 without DDT were not furnished the writer for testing, it is possible that some of the other ingredients of these dips had a deleterious effect upon the test insects. However, the experience of the writer with other materials indicates that the excellent resistance here recorded is due to the DDT content of the dip used.

If the results of these laboratory tests are borne out in warehouse practice, dipping goats in a DDT solution a few days before they are sheared should result in a freedom from insect damage in the stored fleeces, at least until the mohair is scoured prior to manufacture into fabrics.—11-29-46.

DDT Used to Control a Rice-Field Mosquito, *Psorophora confinnis*[1]

WILLIAM R. HORSFALL, *Fayetteville, Arkansas*

The midsummer generation of the dark rice-field mosquito, *Psorophora confinnis* (Lynch-Arribálzaga), may be controlled by distributing powdered DDT over a dry field prior to the second irrigation. By applying a combination of DDT and a nitrogenous fertilizer no additional farm operation is necessary. When irrigation water enters the field, and the toxic agent is already present, development of larvae can be prevented. Observations reported here were made during 1946 at the Rice Branch Experiment Station, Stuttgart, Arkansas.

Previous attempts to obtain uniform dispersal of DDT in rice fields based on emulsifying a concentrate in irrigation water have been only partially successful. At varying distances from the point of entry of the treated water, a field becam habitable to larvae. In five of six tests carried out by Knowles & Fisk (1945), larvae of the dark rice-field mosquito were completely eliminated from that part of a field within 400 feet from the point of entry of an emulsion containing 0.2 p.p.m. of DDT. When the concentrate was added to irrigation water at the pump and conveyed through a canal, effectiveness was reduced in proportion to the length of the canal. Wisecup, *et al.* (1946) confirmed the work of Knowles & Fisk regarding lost effectiveness of DDT in proportion to distance an emulsion was carried from the point of release. Problems incident to adjusting and maintaining an apparatus for releasing DDT emulsions make the method of dispersal tedious and may prevent general acceptance.

Wisecup & Deonier (1945) have used DDT as dust for control of the dark rice-field mosquito in small areas of natural sites. A dust containing 0.1 pound of DDT per acre controlled larvae when applied to sites after hatching had begun. Dusts when applied at the rates of 1.0 and 0.1 pound of DDT per acre did not control larvae when potential sites were treated 28 and 17 days respectively before flooding (*ibid*).

SEASONAL HISTORY.—The method of control of the dark rice-field mosquito outlined here is related directly to the seasonal history of the mosquito. Eggs are laid in rice fields when they have been drained during the summer. After the soil has dried to the point of cracking a field is irrigated again. Eggs begin to hatch within a few minutes after they are covered with water, and normally all have hatched within 12 hours. Adults emerge within a week under mormal summer temperatures. No subsequent generation arises from a rice field unless it is drained and irrigated again (Horsfall 1942a).

The first generation that develops in

[1] Journal Series No. 820. Published with permission of the Director of the Arkansas Agricultural Experiment Station.

rice fields comes from hibernating eggs deposited during the preceding season (Horsfall 1942b). Fields planted to rice after pasturing the preceding season had nearly 40 times as many larvae in them as had fields following any other treatment. This generation may be controlled by not pasturing land the season before rice is planted.

Roadside ditches are secondary sources of this mosquito (Horsfall 1942a). In Arkansas county nearly 3000 acres of ditches are present, but this area is minor compared to that in rice. Area for area ditches are less frequently sources of larvae than newly flooded fields. Ditches produced less than one per cent of larvae in the rice area.

METHODS.—The most convenient method of applying DDT for control of the summer generation of the dark rice-field mosquito in fields is to broadcast it with fertilizer. Usually the fertilizer is broadcast as pellets from an endgate seeder on a two-wheeled cart as it is drawn at measured intervals across a field. The fertilizer is a suitable diluent and carrier for DDT and should be distributed uniformly in order to be available to the rice.

A non-wettable powder containing 50 per cent of DDT was used in all tests in 1946. It was mixed with a granulated nitrogenous fertilizer (Cyanamid) on a concrete floor by two persons using shovels. The mixture was shovelled into bags for transfer to the field. Lots of 200 pounds of fertilizer and 4.0 pounds of a dust containing 2.0 pounds of DDT were mixed at one time for the field tests, and smaller lots of 15 pounds of fertilizer and various dosages of DDT were mixed for the plot tests.

Plot tests were carried out in a row of 15 plots, each one-tenth acre in area, and the field test involved a treated area of 13 acres and check area of 6.5 acres. Dosages of DDT used in plots were 0.0, 0.25, 0.5, 1.0 and 4.0 pounds to an acre, and each dosage was repeated three times in plots selected at random. Irrigation of plots and field was begun on the day treatments were made. Plots were small enough to be flooded the same day, but the field required three days to inundate.

Examinations for larvae were made on the fourth day after flooding was completed. Random samples of one square foot were examined by means of an area sampler. The device consists of a cylindrical screen cage with a cross-sectional area of one square foot (Horsfall 1942b). The cylinder is 13 inches high and is open at both ends. Support and weight are provided by a metal band at each end of the cylinder and four metal struts between them. In use the device was dropped at random intervals in a rice field in such a way that one end settled into the mud, and the walls enclosed larvae present under one square foot of water surface. As they rose to the surface larvae were dipped out and counted.

RESULTS.—Initial results on field scale showed complete kill of larvae when 2.0 pounds of DDT were applied to an acre. Fertilizer (as Cyanamid) was applied to both areas at a rate of 200 pounds to an acre. The check area showed a mean population of 3.2 ± 0.6[1] larvae to a square foot based on 22 square feet selected at random. No larvae were found in 90 square feet in the treated area.

Initial control in plots of one-tenth acre showed that hand broadcast applications of DDT in fertilizer killed larvae of *Psorophora confinnis* in dosages as low as 0.5 pound to an acre. Dosages ranged from zero to 1.0 pound in 150 pounds of fertilizer to an acre. Mean larval population in three check plots was 3.7 ± 0.8 larvae to a square foot based on examination of a total of 30 square feet. All other plots were free of larvae except for one larva found in 30 square feet in a plot treated with 0.25 pound of DDT per acre.

DDT was toxic to larvae for several days in the field where the dosage was 2.0 pounds per acre. One day after treatment 80 larvae of *P. confinnis* in the fourth instar were placed inside a hollow square formed by a band of sheet metal set on edge. No larvae were alive the next day. In another part of the field a similar area was enclosed four days after flooding, and in it were placed 128 larvae (8 to a square foot) in the third and fourth instars. One day later the larval population of this square was 2.5 ± 0.6 larvae to a square foot or about 30 per cent of the original population.

A dosage of 4.0 pounds of DDT per acre showed residual toxicity for 17 days to

[1] Standard error.

larvae of *Anopheles quadrimaculatus* Say, a species that lays its eggs on water. Only four larvae were present in 20 square feet in the treated plots when 56 larvae were observed in a similar area in check plots.

Larvae of a later generation of the dark rice-field mosquito developing after a third irrigation of plots were not killed by a dosage of 0.5 pound of DDT to an acre which had been applied during the first drainage period 44 days earlier. Two plots treated and flooded June 26 were drained July 15. One week later they were unavoidably flooded by a heavy rain, and that water was drained off. On August 9 these plots were irrigated once more. A total of 106 larvae were observed in 20 square feet in these plots.

Certain aquatic insects and eggs of frogs seemed to be resistant to DDT when applied to rice plots in the manner described. Rice water weevils, certain dytiscids and hydrophilids were abundant in all plots four days after treatment. Frogs' eggs were resistant to 0.5 pound of DDT to an acre as was shown by hatching of one mass four days after treatment. Some dead dytiscids and hydrophilids were observed in all plots including check plots. Corixids and notonectids present in puddles along levee ditches at the time of treatment were killed by a dosage of 2.0 pounds of DDT to an acre.

Water that had passed through a field treated with 2.0 pounds of DDT per acre was not toxic to larvae of *Psorophora confinnis* when it was allowed to flood an untreated area along the lower side of the field. As soon as water from the treated part had passed into the untreated area, the channel through the separating levee was closed. Four days later larvae were numerous in the untreated portion, and none was present on the treated side of the levee. Water seeping through a levee into a grassy spot outside the treated field supported a large number of larvae.

SUMMARY.—The midsummer generation of the dark rice-field mosquito, *Psorophora confinnis* (L.-A.), was controlled by the use of DDT in a dry mixture with a nitrogenous fertilizer when broadcast over a field immediately before the second irrigation was begun. Uniform distribution was obtained by broadcasting a DDT-fertilizer mixture with an endgate seeder as it was driven across the field at measured intervals. No larvae were found in a field treated with a dosage of 2.0 pounds of DDT in 200 pounds of a granulated commercial fertilizer to an acre when an adjacent check field produced a mean population of 3.2 ± 0.6 larvae to a square foot. Similar dry DDT-fertilizer mixtures when applied by hand broadcast over one-tenth-acre plots gave complete control with dosages as low as 0.5 pound of DDT to an acre when the mean population in check plots was 3.7 ± 0.8 larvae. An application of 2.0 pounds of DDT to an acre was lethal to larvae in the fourth instar when they were placed in a treated field one day after irrigating began. Nearly 70 per cent of larvae in the third and fourth instar were killed when they were placed in a treated field four days after irrigating it. Water that had passed through a field treated with 2.0 pounds of DDT to an acre was not toxic to larvae when it was allowed to flood an untreated area along the lower side of the field.

Larvae of *Anopheles quadrimaculatus* Say were reduced in plots 17 days after treatment with 4.0 pounds of DDT to an acre. Check plots showed 56 larvae and treated plots four larvae in 20 square feet.

Dytiscids, hydrophilids and rice water weevils seemed to be resistant to dosages up to 4.0 pounds of DDT to an acre. Frogs' eggs were resistant at least to 0.5 pound of DDT to an acre when applied in the manner described.—11-5-46.

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Cub Airplanes in the South Pacific for Application of DDT

B. V. Travis,[1] J. D. Maple,[2] H. S. Hurlbut,[3] and C. N. Husman,[4]
U. S. Naval Medical Research Unit Number 2[5]

In April 1944 spray equipment for a Cub airplane and supplies for both ground and air applications of the new insecticide, DDT, were taken to the South Pacific. Methods of application of DDT that had just been developed in the States (Deonier *et al.* 1945; Deonier & Burrell 1945) were to be tested in combat areas. These first tests of aircraft applications of larvicides in the South Pacific were conducted on Guadalcanal, June 9, 1944, in cooperation with Island Malaria Control Units. The striking results of the tests, and others in the Southwest Pacific, stimulated various groups in the Pacific theater to use aircraft for this purpose with increasing frequency, the most intensive use being at Iwo Jima and Okinawa.

Breeding Area.—In general, the South Pacific breeding areas for *Anopheles farauti* Laveran were man made, *e.g.*, road ruts, barrow pits, fox-holes, revetments, bomb craters, and shell holes. There were frequently acres of road ruts sufficiently deep to hold water during the dry season. So important were such water catchments that *A. farauti* might easily be called the "road rut mosquito."

The typical prewar breeding occurred in large swampy areas filled with depressions and debris. Important natural locations were also along the margins and at the mouths of streams that were blocked by sand bars. During the wet season, these streams cut through the sand bars and flushed sufficiently often to control mosquito breeding.

Materials and Methods—The spray equipment for the Piper Cub (L-4-B, 65 H.P.) was the venturi apparatus developed by Husman & Longcoy. The material sprayed was a 5 per cent DDT solution in a 50-50 mixture of diesel oil and S.A.E. 10 lubricating oil. One test, No. 3. was made with a 5 per cent DDT-water emulsion (prepared from emulsion concentrate containing 20 per cent DDT, 20 per cent *Triton X-100*, and 60 per cent xylene).

In all tests the rate of application was from 3 to 4 pints per acre. Swaths of 40 to 55 feet were flown as close to the vegetation as safety permitted. Over grasslands the altitude was 15 to 20 feet, whereas over trees it was at times as great as 175 feet. In most instances, it was possible to fly cross wind; however, with the rapid changing of wind direction, some of each flight was necessarily either with or into the wind. Usually the pilot was guided in his swaths by "flagmen."

Observations on results were made by selecting, at random, a number of water catchments that contained mosquito larvae. The populations of both *Culex* and *Anopheles* larvae were determined by dipping both before and 24 hours after treatment.

Results.—A number of tests were made on Guadalcanal and Bougainville in typical breeding areas. A short description will be given of a few of these tests to demonstrate results in different types of cover. It will be noted that in no case did 2 quarts of a 5 per cent solution fail to give adequate control of *Anopheles*, *Bironella*, or *Culex annulirostris* Skuse, regardless of the density of the vegetation which varied from open grasslands to extremely dense tropical jungles. These light applications of DDT were effective in killing larvae present at the time of treatment; however, the larvae hatching the first day after treatment usually were not killed, so that weekly treatments were necessary. Results of tests 1, 2, 4, and 5 are summarized in table 1, the remainder are summarized only in the text.

Test 1.—This area of 100 acres was composed of partially cleared woods and jungle, and open grassland. The trees were about 150 feet high with clear areas underneath the upper canopy. The grasslands were covered with grass 3 to 6 feet

[1] Lieutenant, H(S), U.S.N.R., on military leave from the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.
[2] Lieutenant, H(S), U.S.N.R., killed in action on Okinawa.
[3] Commander, H(S), U.S.N.R.
[4] Naval Civilian Technician from the U.S.D.A.
[5] The writers wish to express their appreciation of the Malaria Control and Malaria Survey Units on both Guadalcanal and Bougainville for their assistance and cooperation which made these tests possible.

high. The breeding was largely in road ruts and depressions resulting from logging operations. Of the 20 locations checked before treatment, 16 contained *Anopheles* and 16, *Culex*. In the post-spraying check, only one location contained *Anopheles* and two, *Culex*. The data in table 1 are based on 5 dips in each of 20 locations; however, many additional dips were made in each location and in other locations after spraying in order to be certain that no live larvae were overlooked. The catchments containing live larvae received no spray and were at the margin of the plot. This was due to flight error as the pilot changed from his low altitude swaths over grasslands to high altitude swaths over trees.

Test 4.—This test area, 25 acres, was covered by a large, round clump of tall trees with a dense understory of jungle surrounded by typical grasslands. In addition to the data in table 1 for this test, which were obtained from 1 dip in each of 110 selected locations, 1538 *Anopheles* were taken with an extra 500 dips over the general area prior to treatment. Following spraying, no *Anopheles* larvae were found in the selected locations and an extra 700 dips also showed no *Anopheles*. A small number of recently hatched *Culex* were found in these additional dips. All the initial population of *Culex* was killed by the spray.

Table 1.—Results of airplane spray applications with DDT-oil solutions for the control of mosquito larvae; Guadalcanal, 1944.

Test Number	Before Treatment			After Treatment			Per Cent Control	
	Number of dips	Number of larvae		Number of Dips	Number of larvae			
		Anopheles[1]	*Culex*[2]		*Anopheles*	*Culex*	*Anopheles*	*Culex*
1	20[3]	48	285	20[3]	3	5	93.7	98.2
2	17[3]	11	154	17[3]	0	3	100	98.1
4	110	600	1060	110	0	0	100	100
5	146	758	4011	279	1	35	99.9	99.5
Total	293	1417	5510	426	4	43	99.7	99.5

[1] Mostly *A. farauti*.
[2] *C. annulirostris*.
[3] In tests 1 and 2 the data are based on an average of five dips at each of 20 and 17 locations, respectively.

Test 2.—This 150-acre area was open grassland with breeding in the many road ruts interlacing all over the area. The grass was 3 to 6 feet high, but the roadways and ruts were nearly bare of vegetation. Of the 17 locations checked before treatment, 5 contained *Anopheles* and all contained *Culex*. After treatment no *Anopheles* were present and *Culex* occurred in only one location. The one location where *Culex* mosquitoes were found after spraying was at the end of the area and was not sprayed; the pilot cut off the spray too soon. The data shown in table 1 were obtained exactly as for test 1.

Test 3.—This test of 150 acres was in the same block of land and was identical to test 2, except that a 5 per cent emulsion was used instead of an oil solution. Water catchments were numerous over the entire area and all water contained larvae prior to spraying. There was a complete kill of all *Anopheles* and *Culex* in the area treated.

Test 5.—This test area, 25 acres, was in a typical coconut grove where the trees were 75 or more feet high. As the grove had been unattended for many months, there was a rather dense understory of tropical plants and small coconut trees. The breeding was in road ruts between the rows of trees. It should be pointed out that in the 146 locations checked 26 of the 35 *Culex*, recorded in table 1, were newly hatched and the one *Anopheles* larvae was so badly affected that it would not have recovered. Beyond the treated area, but within the grove, *Culex* larvae were killed up to 400 feet downwind from the last swath.

At Bougainville several tests were made in some swamps and lagoons that were the extreme of tropical conditions both for vegetation and debris. Three such *Anopheles* areas sprayed showed complete kill; however, at the time checks were made

there were some larvae that had hatched after the spray was applied. In a swamp area in which there were *Bironella*, a 94.5 per cent control was obtained; however, if the larvae found in an area where the pilot had cut off the spray too soon are omitted from consideration, the control would have been 99.4 per cent. A small island which was lightly wooded with tall trees in the center and thick undergrowth around the margin was sprayed. A 94.8 per cent control of *Culex* resulted even though the pilot received no guidance in swath width. This pilot did not have previous experience with airplane spraying.

No special counts were made to determine accurately how effective these treatments were against adult mosquitoes. Several observations, however, in areas where there was a small population of *Aëdes* adults indicated that large reductions in the adults were obtained with the larviciding sprays, such as have been reported by Lindquist *et al.* (1945).

DISCUSSION.—It was of special interest to find that satisfactory control could be obtained with the Cub spray apparatus even when natural obstructions made it necessary to fly as high as 175 feet. Complete control of larvae breeding was obtained even under a dense canopy of vegetation. Many observations of small water catchments that were completely overhung by the broad-leafed vegetation showed that the smaller droplets of the spray reached such locations in sufficient amounts to control mosquito larvae. Also, experience with *Culex quinquefasciatus* Say had indicated that such light applications of DDT would not control *Culex* mosquitoes. The *Culex annulirostris*, however, appeared to be as susceptible to DDT as *Anopheles farauti*.

The feasibility of small aircraft for mosquito control was well demonstrated on Guadalcanal. Frequently the natural obstacles and the wind direction would have made the use of larger and faster aircraft impractical. There were, of course, large areas that could have been handled much more rapidly with larger and faster planes. Even in areas where larger planes would be desirable, there were always small areas that could best be handled by spot spraying with small aircraft.

The aircraft applications were especially desirable in areas where there was a confusing tangle of ruts, and a multitude of small pockets of water. Also, there were rather large areas almost inaccessible to the spray crews. It was impossible for the men to find each individual, isolated pocket of water and to treat the area as thoroughly as could be done with air applications. In addition, air applications assisted in control by reducing the adult populations.

SUMMARY.—Application of DDT as a mosquito larvicide by means of Cub airplane was demonstrated to be very effective in the South Pacific. No area was observed where *Anopheles farauti* Laveran or *Culex annulirostris* Skuse could not be controlled with an application of 2 quarts of a 5 per cent oil solution or a 5 per cent water emulsion of DDT applied by air.

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"The Committee of Food Sanitarians, an organization for the accumulation and dissemination of information relating to the problems of insect and rodent control within the food processing industry, announce the election of officers for 1947: Chairman, E. M. Searls; Vice-Chairman, E. L. Holmes; Secretary, J. P. Barrett; Treasurer, G. S. Doolin."

Development of Spraying Apparatus for HNS-1 Helicopter

J. S. Yuill,[1,2] C. C. Deonier,[2] C. B. Wisecup[2] and G. W. Girdler[3]

The first applications of aerial sprays from rotary-wing aircraft were made by means of autogiros in 1936 (Francis 1936; Potts 1939; Whitten *et al.* 1941). This early work demonstrated that sprays could be controlled better than dusts when applied from the air, and that slow-moving rotary-wing aircraft was suitable for aerial spraying.

In conjunction with the development of DDT sprays for the control of mosquitoes, the United States Navy and the United States Coast Guard desired that such sprays applied from a helicopter be tested to determine the scope and possibilities of using such aircraft in control of malaria. Spraying from fixed-wing aircraft had given satisfactory control of mosquito larvae (Deonier & Burrell 1945) and adults (Lindquist *et al.* 1945). Accordingly a cooperative project was undertaken jointly by the United States Navy, the United States Coast Guard, and the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. The types of apparatus tested, and some results which have been secured, are described in this paper.

Helicopter.—The helicopter used for these studies was a Coast Guard HNS-1 (Army R4-B) (Fig. 1), a two-place trainer and liaison aircraft and the first production model helicopter developed in this country. In this aircraft vertical and translational lift are provided by the main rotor, consisting of three blades, or airfoils, each 17 feet 4 inches long, which turn in a horizontal plane. A tail rotor having three blades, each 4 feet long, rotates in a vertical plane to counteract torque and to serve as a rudder. The direction and magnitude of the resultant forces set up by the rotors are controlled by changing the pitch of the blades. Power is supplied by a radial air-cooled engine rated at 200 hp. at 2450 r.p.m. The range of speed is minus 15 to plus 75 m.p.h., and the normal cruising speed is 50 to 60 m.p.h.

According to the manufacturer's specifications, under sea-level conditions the maximum vertical ascent at zero air speed is 100 feet and the service ceiling is 14,000 feet. Performance is reduced as the temperature and humidity increase. Fuel consumption is approximately 12 gallons per hour and the cruising range about 2.25 hours. The net allowance for spray material when a full tank of fuel is carried is only 57 pounds. However, by carrying only half a tank of fuel and removing one seat, the doors, and the cowling, the allowance for spray was increased to 147 pounds (21 gal.). On several occasions 30 gallons was carried, an overload of approximately 60 pounds.

Fig. 1.—Helicopter, equipped with spray boom and exhaust stacks, in flight.

Spray Apparatus.—Since the flow of air about the helicopter varies with the air speed, it was considered that a pressure system would maintain a more uniform flow rate and atomization at different speeds than would an air venturi or other apparatus designed for fixed-wing aircraft, in which the air speed is fairly constant during spraying operations. The apparatus used in the helicopter consisted of a 30-gallon tank mounted just back of and

[1] Lieutenant Commander, H(S), U.S.N.R., now with the Bureau of Entomology and Plant Quarantine.

[2] Entomologists, U.S.D.A., Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine, working under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development.

[3] Lt. Commander, U. S. Coast Guard, assisted in the work.

above the seat. Metal tubing carried the spray liquid by gravity to a large fuel strainer and then to an hydraulic pump mounted on an accessory driving pad on the engine. With this direct drive the pump was in operation whenever the engine was running. The discharge line from the pump led to an adjustable relief valve and a selector valve mounted near the pilot's seat. A by-pass line returned the excess liquid from the relief valve to the spray tank during spraying. A similar by-

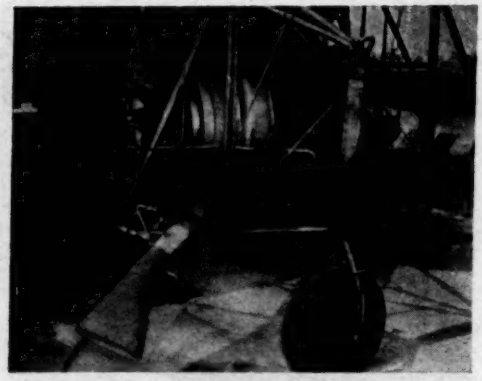

FIG. 2.—Close-up of nozzle boom beneath tail of helicopter.

pass line was installed between the selector valve and the tank, so that the liquid circulated at zero pressure when spray was not being dispersed. The maximum flow rate was 5.5 gallons per minute and the pressure range to 1500 pounds per square inch (p.s.i.).

This apparatus was highly satisfactory for pumping oil solutions of DDT. DDT emulsions could be sprayed, but it was necessary to flush out the system at the end of each day and to make frequent inspections of the liquid seal ring on the pump shaft, as the emulsion solvent caused some deterioration of the synthetic rubber grommet in the seal ring. DDT suspensions cannot be used with this pump. At times fine sediment in the spray material interfered with the operation of the pump and relief valve. This difficulty was minimized by straining the material through an 80-mesh screen.

The equipment could be improved by using an electrically driven pump rather than the engine-driven type. With an electrically driven pump, which would be in operation only during the actual discharge of the spray, the pilot would simply flip a switch mounted on the azimuth stick to turn the spray on or off. Unfortunately, pumps suitable for operation on the electric system of this model helicopter are not available.

A dual-pump pressure system, consisting of a hydraulic pump for spraying solutions and a centrifugal pump for spraying emulsions or suspensions and for transferring spray material from the ground supply to the tank, was discarded because the centrifugal pump would not build up adequate pressure. A gear pump was also tested and found to be unsatisfactory.

Two general types of atomizing apparatus were tested—(1) Various conventional nozzles, and (2) equipment utilizing the flow of exhaust gases from the engine. The second type of equipment, in common with similar apparatus for other types of airplanes, produced a combined spray and smoke which was highly spectacular but somewhat inefficient, owing to the loss of effective spray as smoke particles. Major emphasis was placed on securing comparable results from the use of nozzles.

Selection of Nozzles.—To develop a means of atomizing the sprays containing DDT so that the majority of the droplets had diameters of less than 100 microns, the droplet spectra from a large number of nozzles were secured at various pressures by measuring the drops which were deposited upon glass slides exposed to trial flights of the helicopter. The discharge rates for the five most promising nozzles were then calibrated. On the basis of these data, which are presented in table 1, future development was limited to the following nozzles: (a) TT8001 for the lower portion of the droplet range, (b) modified fern-type 55-gage for the upper portion of the range, and (c) modified fern-type 70-gage for a broad range of droplet sizes. The boom upon which these nozzles were attached was suspended beneath the fuselage just forward of the tail section (fig. 2) at a point just below the outer edge of the rotor disk. In addition, a few tests were made with the breaker-bar equipment which had been designed by C. N. Husman for fixed-wing aircraft.

Two types of apparatus were employed for the exhaust generation of spray—(1) an extension of each exhaust stack terminating in a venturi constriction, the

Table 1.—Droplet spectra and discharge rates of nozzles used to spray DDT from a helicopter.

Type of Spray and Nozzle Used	Pressure	Drops Measured	Per Cent of Droplets in Size Range Indicated						Discharge Per Minute[1]
			10–40 Microns	41–80 Microns	81–120 Microns	121–160 Microns	161–200 Microns	201+ Microns	
	P.s.i.	*Number*							*Quarts*
Hollow-cone spray:									
Bean 52	150	104	2.9	38.5	25.0	12.5	7.7	13.4	—
Brown 60	60	145	2.8	22.8	23.4	17.9	17.2	15.9	—
Furnace jet 57	125	70	4.3	32.9	21.4	18.6	18.6	4.2	—
	60	69	2.9	29.2	26.0	7.3	15.9	18.7	—
Hudson 76	150	54	—	18.5	20.3	24.1	25.9	11.2	0.60
Hudson 59	150	108	12.1	35.1	23.0	16.7	9.3	3.8	—
Hudson 58	150	120	11.7	31.8	20.8	13.3	9.2	13.2	—
LNN2	150	58	46.6	37.9	13.8	1.7	—	—	.32
	60	130	30.0	34.6	17.7	8.5	6.1	3.1	.24
LNN4	150	113	22.1	46.0	24.8	5.3	1.8	—	—
Solid-cone spray:									
GG2	125	95	18.8	25.2	24.2	11.6	3.2	17.0	—
	60	89	1.1	21.4	23.5	21.4	13.5	19.1	—
GG3	125	71	1.4	18.4	16.9	16.9	16.9	29.5	—
Flat spray:									
TTL	125	106	16.9	44.4	19.8	8.5	5.7	4.7	—
	60	81	1.2	18.5	18.5	23.6	22.2	16.0	—
TT8001	150	75	40.0	44.0	10.6	5.4	—	—	.68
	60	130	10.8	36.8	21.6	16.2	10.0	4.6	.48
TT8002	150	100	30.0	28.0	23.0	9.0	2.0	8.0	—
Discoid spray:									
Fern Type 70	150	128	12.5	44.5	29.7	10.1	2.4	.8	1.08
	60	111	15.3	19.9	22.5	15.3	8.1	19.9	.64
Fern Type 55	150	46	—	4.4	13.0	15.2	34.8	32.6	6.40
Fishtail stacks	15	101	22	50	17	4	4	3	20.4

[1] Determined on ground except for fishtail stacks. These figures were found to be lower than those observed in actual operation.

spray material being injected into the throat of the venturi, and (2) an unconstricted fishtail extension containing a small aircraft carburetor venturi through which the spray is injected. The first piece of equipment was unsatisfactory because most of the spray was dispersed as a smoke and, in addition, the constriction created sufficient back pressure against the engine to be a hazard for slow flight. Although the fishtail stack (Fig. 3) also vaporized a portion of the spray, it was possible to adjust the point of injection of the liquid to a proper distance from the engine so that the discharged spray contained a minimum of vapor and excessively large droplets.

Swath-Width Studies.—To determine the effective swath width, the amount of toxic material deposited at any given location was evaluated by recording (1) the size of the drops which settled upon glass slides coated with magnesium oxide, (2) the 24-hour mortality of larvae of *Anopheles quadrimaculatus* Say exposed in half-pint cartons containing distilled water, and (3) the time for immobilizing adult houseflies placed in previously exposed petri dishes.

A single flight of the helicopter, properly equipped with the apparatus under test, was made directly into the wind over a line of 10 stations set up at right angles to the wind direction. The stations were arbitrarily placed 20 feet apart. A single slide, a carton of larvae, and a pair of petri dishes were placed at each station. A large number of flights were made with pieces of apparatus operating singly on either side of the craft to determine whether there were marked differences in the air flow characteristics. The data for the flights with a complement of orifices are presented in table 2.

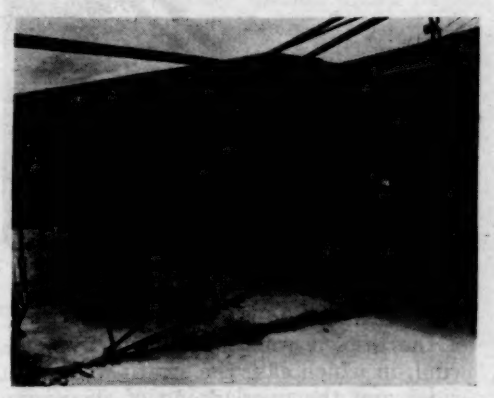

FIG. 3.—Close-up of fishtail stack.

Table 2.—Data relating to swath-width studies made with a helicopter.

Equipment	Diameter of Orifices	Pressure	Delivery	Attitude	Wind	Cross Drift[1]	Effective Swath Width as Determined by—		
							Slides[2]	Mosquito Larvae	Adult Flies
	Inches	*P.s.i.*	*Qt. per Min.*	*Feet*	*M.p.h.*		*Feet*	*Feet*	*Feet*
Pressure atomization:									
Fern-type 60 gage (8 orifices)	0.04	250	16.4	40	4	+	80	100	100
Fern-type 70 gage (8 orifices)	.028	150	6.4	40	4	0	80	80	80
		250	9.2	40	4	0	60	60	60
TT8001 (16 orifices)	.020	150	13.6	40	5	+	120	120	120
		150	13.6	40	10–15	0	60	No test	100
		150	13.6	80	10–15	+	60+	No test	100+
		250	18.4	30	10	++	60	40	60
		250	18.4	40	10	++	80	80	80
Breaker bar (48 orifices)	.0135	150	16.4	30	15	0	60	60	80
		250	20.0	30	15	++	60	60	60
Exhaust atomization:									
Fishtail stacks (24 orifices)	.0635	15	20.4	30	15	0	60	80	60
		20	20.4	40	6	+	120	120	140
		20	20.4	40	10	+	80	40	80
		20	20.4	40	10–15	+	80	No test	100
		20	20.4	80	10–15	+	100	No test	140

[1] Cross drift estimated as follows: 0 = none; + = swath displaced but measurable; ++ = swath displaced beyond limit of stations width estimated.
[2] Deposit of at least 3 mg. per square meter.

In general the results from the three methods of evaluation were in close agreement. When the helicopter was flown into the wind at cruising speed, the minimum effective swath width for all types of spray apparatus tested was 60 feet. Greater widths were achieved in low wind velocities, and there was some indication that a wider swath could be secured by flying at a higher altitude than at the arbitrarily selected height of 30 feet; therefore, a swath width of 60 feet between flights was used in all subsequent spraying. In some

FIG. 4.—Aerial view of smoke.

of the tests it was desirable to fly cross wind, in which case the swath was much wider and the overlapping of successive swaths gave an even coverage.

After the effective swath width for each flight was determined, and since the normal cruising speed of the plane was known it was necessary to calculate the amount of material needed to give coverage at any desired rate of application. At the rate of 2 quarts of liquid per acre, a delivery of 14.4 quarts of spray per minute was required. This rate could be supplied by 17 of the TT8001 nozzles at 150 p.s.i. or by 5 of the 55-gage fern types at 75 p.s.i.

Observations on Performance.—The performance of the helicopter was not affected by the addition of spray equipment, with one exception. When the spray tank was half full of liquid, the shift of fluid could be felt when the helipcoter was turned, but the effect was not dangerous. For extensive operations a baffled tank would be recommended.

The tremendous down draft which is characteristic of a hovering helicopter was less pronounced when spraying was conducted at normal cruising speeds. In cruising flight the smoke portion of the exhaust-generated spray was frequently thrown into a double roll about 100 yards behind the plane, as shown in figure 4. It is reasonable to assume that spray droplets were subjected to the rolling action, but probably to a lesser degree because they are heavier than smoke particles.

Observations showed that in normal flight the down draft takes place about 100 to 200 feet back of the aircraft. The

force is not nearly so violent at this speed as in hovering or slow flight and is often obscured by the effects of wind or convection currents.

Hot weather and low wind velocity definitely decrease the vertical-lift efficiency of the HNS-1 and extreme care must be exercised when the helicopter is flown at low altitudes. Applications at slow speeds (5 to 10 miles per hour) should always be made into the wind. Cross-wind flights are not considered safe at speeds less than 30 miles per hour. The HNS-1 can operate safely in winds well in excess of the maximum (15 m.p.h.) recommended for spraying DDT with aircraft.

sions. Applications were also made to two salt-marsh areas. The data on acreage, amount of material, and time required for the different operations are presented in table 3. The helicopter was given the routine maintenance check every 30 hours, but the time required is not included.

These applications were designed to compare materials, and thus required more ferrying and loading time than would have been necessary in routine mosquito-control applications. The ferrying distances for the sink holes were about the same for both types of aircraft, but the helicopter sprayed two more materials than did the Cub, thus requiring

Table 3.—Comparative efficiency of a helicopter and a Piper Cub (L-4B) airplane.

Type of Breeding Area and of Aircraft Used	Area Treated	Amount of Spray	Loads	Ferry Time	Spraying Time	Time for Repairs
	Acres	*Gallons*	*Number*	*Minutes*	*Minutes*	*Days*
Sink holes						
Helicopter	20.5	38.5	5	38	42	2
L-4B	23.0	25.1	3	12	38	0
Salt marsh						
Helicopter	63	40	2	16	20	0
L-4B	65	35	2	80	20	0

COMPARATIVE EFFICIENCY OF THE HELICOPTER AND FIXED-WING AIRCRAFT.—Two series of tests were carried out prior to the mosquito-breeding season to compare the efficiency of the helicopter with that of light airplanes in spraying DDT for control of mosquito larvae. Several series of prebreeding treatments, in areas known to produce large broods of salt-marsh mosquitoes were being made just before the beginning of the rainy season. A number of areas were treated with the helicopter, a Piper Cub (Army Air Forces designation L-4B), or a Stearman (Navy designation N2S). Unfortunately, drought so delayed the mosquito season that the effect of the DDT deposits was lost and no comparisons could be made between the effectiveness of application by the different types of aircraft. Comparisons have been made, however, on the efficiency of the planes.

Comparison with Piper Cub.—The helicopter and a Piper Cub were used to spray an equal number of scattered sink holes or seepage areas of about 1 acre each with either DDT oil solutions or water emul-

more ferry time. The average ferry time for the Cub was somewhat less than that for the helicopter, but the average treatment time was much less for the helicopter, owing to its greater maneuverability.

The advantage of the helicopter over that of the Piper Cub was its ability to land in small openings in the salt-marsh areas for reloading. Since the air strip nearest the marshy islands under treatment was 16 miles away, the L-4B required nearly 45 minutes to reload and return. In contrast, the helicopter reloaded in a nearby clearing in the woods, requiring only 12 minutes between treatments.

Comparison with Stearman N2S.—This series of tests, carried out in conjunction with the mosquito-control program at the Naval Air Station, Banana River, Fla.[4] was designed to compare applications made with the helicopter and the Stearman biplane to paired plots. The applications were made by each airplane to similar areas of large rectangular blocks of salt marsh, to scattered irregular marshy is-

[4] Lt. James Weatherell, U.S.N.R., and Ens. T. S. Roberts, H(S), U.S.N.R., cooperated in these tests.

lands, and to small acreages of fresh-water sink holes. A spray of 5 per cent of DDT in diesel oil was used for all applications.

The Stearman biplane was equipped with a 56-gallon tank and a belly-venturi. Spraying was done at a speed of 39 miles per hour with a swath interval of 100 feet. It was necessary to return to an established air strip for reloading.

Table 4.—Comparative efficiency of a helicopter and a Stearman N2S airplane.

Type of Breeding Area and of Aircraft Used	Area Treated	Amount of Spray	Loads	Ferry Distance	Ferry Time	Spraying Time	Service Time	Time for Repairs
	Acres	*Gallons*	*Number*	*Miles*	*Minutes*	*Minutes*	*Minutes*	*Minutes*
Rectangular salt marsh:								
Helicopter	300	140	5	25	39	46	49	27
N2S	320	182	4	34	18	36	12	0
Island marshes:								
Helicopter	230	109	4	9	19	47	41	0
N2S	240	130	3	32	20	37	6	0
Sink holes:								
Helicopter	30	19	1	14	20	10	10	0
N2S	30	21	1	14	20	6	3	0
Totals:								
Helicopter	560	268	10	48	78	103	100	27
N2S	590	333	8	80	58	79	21	0

The data for these tests, presented in table 4, show that the N2S was definitely more efficient than the helicopter, due to its faster cruising speed, larger useful load, and greater swath width. These advantages completely overbalanced the greater maneuverability and short ferry distance for the helicopter. The difference in service time is not significant, as the use of similar loading equipment would have equalized the service times.

The purchase and operational costs of the helicopter are much higher than those of fixed-wing aircraft. However, improved models are being developed which may be more practical both in cost and performance.

CONCLUSIONS.—Studies were made to determine the possibilities of using a helicopter for applying DDT sprays for the control of malaria-carrying mosquitoes. The following preliminary conclusions apply only to the HNS-1 helicopter, the model used in these studies.

1. An apparatus has been developed for the HNS-1 which will atomize and disperse satisfactorily either oil solutions or water emulsions of DDT, if the spray mixtures are free of sediment.

2. The airflow from this model helicopter is such that a safe effective swath width of only 60 feet is produced with any type of spraying equipment.

3. The HNS-1 is satisfactory for experimental studies. It can be fitted with special equipment for rapid change of spray mixtures and atomizing apparatus to facilitate experimental procedure.

4. The HNS-1 is not recommended for routine control operations because of its limited useful load, narrow swath width, slow cruising speed, and because of its inadequate power for operating under unfavorable conditions.

The greater maneuverability embodied in helicopter aircraft offers many possibilities for its use in insect-control operations which would not be possible with fixed-wing aircraft. This includes not only the dispersion of sprays but also reconnaissance and inspection of inaccessible areas.

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DDT-Xylene Emulsions for Use Against Insects Affecting Man[1]

HOWARD A. JONES[2] and HELEN J. FLUNO, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[3]

Of the several ways in which DDT may be employed, the use of emulsions has perhaps the widest application in the control of insects of medical importance. This type of DDT preparation has been particularly applicable to the needs of the armed forces. Efforts along this line at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine have been directed toward the formulation of a DDT emulsion concentrate (Jones *et al.* 1945a) that could be used by the armed services for several purposes. This article discusses the development of a formula comprising DDT and an emulsifier in xylene.

An emulsion of DDT was first used at this laboratory in April 1943, when cloth was impregnated for the control of body lice. Shortly thereafter several DDT emulsions were formulated for application as anopheline mosquito larvicides. Later emulsions were applied as residual sprays for the control of adult mosquitoes, flies, and other insects (Jones *et al.* 1945c).

REQUIREMENTS OF DDT EMULSIONS FOR MILITARY USE.—For use by the armed forces an emulsion concentrate was needed comprising only DDT and an emulsifier in a suitable solvent. A concentrated stock emulsion containing even a small proportion of water would require increased shipping space and would tend to decrease stability of the formulation. As the work progressed certain primary requirements for a DDT emulsion concentrate became apparent. Those were as follows:

(1) It must mix with water readily to form a satisfactory emulsion without requiring special mixing equipment.

(2) It should form a satisfactory emulsion not only in soft water but also in hard and sea water.

(3) The emulsion formed should be reasonably stable at concentrations used in spraying (0.1 to 10 per cent DDT), but extreme stability is not necessary.

(4) It should be adaptable to as many uses as possible.

(5) It should contain as high a concentration of DDT as is consistent with other requirements.

The emulsion concentrate was originally designed as an all-purpose treatment for louseproofing clothing, as a mosquito larvicide, and as a residual or surface spray against adult insects both indoors and outdoors. This is accomplished by the DDT-emulsifier-xylene concentrate. More recently improved concentrates with a higher flash point and greater retention of DDT on chilling have been developed for the last two purposes.

METHODS OF TESTING EMULSIONS.—Comparisons of physical stability of emulsions have usually been made at a DDT concentration of 1 per cent. Emulsions have been prepared and examined for physical stability as follows:

If the concentrate contains 25 per cent of DDT, for example, 5 ml. is slowly added, with continuous swirling, to 120 ml. of water in a 500-ml. erlenmeyer flask. The unstoppered flask is swirled for exactly 1 minute, and 50 ml. of the emulsion transferred to a nessler tube for observation. Notations on the amount of layer separated, and whether the layer is creamy or clear, are usually made 15 minutes, 2 hours, and 24 hours after preparation. Breaking (separation of oil phase) is especially noted. Test emulsions that appear good in distilled water are repeated in hard and sea water.

A 1 per cent DDT emulsion has been considered satisfactory from the standpoint of physical stability if no appreciable separation has occurred in distilled, hard, or sea water within about 2 hours, and in 24 hours only moderate creaming has occurred with little or no separation of oil phase. This criterion has been based on results obtained with various emulsions in biological tests, particularly as mosquito larvicides and as residual sprays for adult insects. Recently, comparisons of solvents

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[2] Now with the Unit of Entomological Research of Dodge & Olcott, Inc., Baltimore, Maryland.

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and emulsifiers have been made in which the concentrate containing 25 per cent of DDT, 10 per cent of *Triton X-100*, and 65 per cent of xylene has been used as a standard, since emulsions made from this concentrate have proved satisfactory from the insecticidal standpoint in extensive laboratory and field tests.

Concentrates that appeared good from the physical standpoint were tested against mosquito larvae and adult insects. Laboratory tests to determine the effect of emulsions as mosquito larvicides have usually been made by dispersing low concentrations throughout the water and observing how long the treatment remained effective. Emulsions have been evaluated for use as residual sprays by applying to wood and glass surfaces and testing against adult houseflies and mosquitoes.

SELECTION OF SOLVENT.—Ethylene dichloride was the first solvent used at Orlando for an emulsion to impregnate underwear. Other solvents used in early tests of louseproofing clothing and in mosquito larvicide and residual spray work were xylene, tetrahydronaphthalene, *o*-dichlorobenzene, ethyl benzoate, dibutyl phthalate, benzyl benzoate, *K-327* (chiefly methylnaphthalenes), *Carbon Met* (chlorinated coal-tar fraction), and *Velsicol AR-60* (chiefly di- and trimethylnaphthalenes). Numerous other solvents, particularly commercially available aromatic fractions, have since been tested.

Table 1.—Physical stability of emulsions (1 per cent of DDT) showing little or no breaking in 24 hours in distilled, hard, and sea water. Prepared from concentrates containing 25 per cent of DDT, 10 per cent of emulsifier, and 65 per cent of xylene.

EMULSIFIER	PERCENTAGE (BY VOLUME) OF CREAMY LAYER SEPARATED TO TOP IN TIME INDICATED								
	In Distilled Water			In Hard[1] Water			In Sea[1] Water		
	15 Minutes	2 Hours	24 Hours	15 Minutes	2 Hours	24 Hours	15 Minutes	2 Hours	24 Hours
Emulsions Showing No Separation after 2 Hours in Distilled Water									
Triton X-100 (polyethylene glycol alkyl aryl ether)	None	None	None	None	5+	5+	<2	2–5	2–5
Triton X-155 (polyalkyl aryl polyether alcohol)	None	None	None	<2	5+	5+	2–5	5+	5+
Tween 80 (sorbitan monooleate, polyoxyalkylene derivative)	None	None	5+	<2	5+	5+	<2	5+	5+
Span 20 plus *Tween 20* (equal parts)	None	None	None	None	<2	2–5	None	2–5	2–5
Emulsions Showing No Separation after 15 Minutes in Distilled Water									
Emulphor ELA (polyglycol ether ester)	None	2–5	[2]5+	<2	2–5	[2]5+	<2	5+	[2,3]5+
Emulphor ON (alkyl polyglycol ether)	None	2–5	[2]5+	<2	5+	[2]5+	<2	5+	[2]5+
Emulride 820 (cocoanut fatty acids of modified polyglycols)	None	<2	5+	<2	2–5	5+	2–5	5+	[2]5+
Emulride 860 (stearic acid esters of modified polyglycols)	None	2–5	5+	<2	2–5	2–5	2–5	5+	[2]5+
Emulside 880 (oleic acid esters of modified polyglycols)	None	2–5	5+	<2	2–5	5+	<2	5+	[2]5+
Igepal CA. Extra High Conc. (alkyl aryl polyglycol ether)	None	<2	2–5	<2	5+	5+	<2	5+	[2]5+
Nekal RU (alkyl polyglycol ether)	None	5+	[2]5+	2–5	5+	[2]5+	2–5	2–5	[2]2–5
Triton 1339 (alkyl aryl polyether alcohol)	None	2–5	5+	2–5	5+	[2]5+	5+	5+	[2]5+
Tween 60 (sorbitan monostearate, polyoxyalkylene derivative)	None	2–5	5+	<2	2–5	5+	<2	5+	5+
Tween 85 (sorbitan trioleate, polyoxyalkylene derivative)	None	<2	5+	None	<2	2–5	<2	5+	5+
Triton X-100 plus *Emulphor ELA* (equal parts)	None	<2	5+	<2	<2	2–5	<2	5+	5+
Triton X-100 plus *Triton 1339* (equal parts)	None	2–5	5+	2–5	5+	5+	2–5	5+	5+
Triton X-100 plus *Tween 80* (equal parts)	None	2–5	5+	<2	2–5	2–5	2–5	5+	5+
Emulsions Showing Some Separation in 15 Minutes									
Emulgor A (condensed glycol ester of high-molecular-weight fatty acids)	<2	<2	2–5	<2	2–5	2–5	<2	2–5	2–5
Polymerized glycol dilaurate	<2	2–5	5+	<2	2–5	5+	2–5	5+	5+
Polymerized glycol monolaurate	<2	2–5	5+	<2	2–5	5+	2–5	5+	5+
Polymerized glycol monooleate	<2	2–5	5+	<2	2–5	5+	<2	2–5	5+
Stearate 61-C-2280 or *75H-14S* (a polyalkylene glycol stearate)	<2	<2	2–5	<2	5+	5+	<2	2–5	2–5
Tween 20 (sorbitan monolaurate, polyoxyalkylene derivative)	<2	2–5	5+	<2	5+	5+	2–5	5+	5+
Tween 86 (sorbitan monooleate, polyoxyalkylene derivative)	<2	<2	5+	None	2–5	2–5	2–5	5+	5+
Span 60 plus *Tween 60* (equal parts)	2–5	2–5	2–5	<2	<2	2–5	<2	2–5	2–5
Span 80 plus *Tween 80* (equal parts)	<2	2–5	5+	<2	2–5	5+	<2	5+	5+
Triton X-100 plus *Alkanol WXN* (equal parts)	<2	2–5	5+	<2	<2	2–5	<2	2–5	[2]5+
Triton X-100 plus *Tween 20* (equal parts)	<2	2–5	5+	<2	5+	5+	2–5	5+	5+
Triton X-100 plus *Tween 60* (equal parts)	<2	2–5	5+	<2	5+	5+	2–5	5+	5+

[1] Artificial hard water containing 500 p.p.m. of magnesium sulfate, 500 p.p.m. of calcium chloride, 250 p.p.m. of sodium bicarbonate. Natural sea water used.
[2] Main portion of emulsion clear or almost clear.
[3] Slight breaking.

These solvents and many others, together with their important physical properties, are listed in a previous article (Jones *et al.* 1945b). Cyclohexanone was tried but, since water is appreciably soluble in this solvent crystallization and separation of DDT occurred in emulsions using this material only. When certain proportions of cyclohexanone were used with xylene, tetrahydronaphthalene, *Velsicol AR-60*, or kerosene, this crystallization of DDT did not occur. Certain combinations of xylene and kerosene gave emulsions which might be useful for some purposes.

To be useful in impregnating clothing for louse control it was necessary that the solvent be volatile, so that a solution of DDT would not remain in the cloth and thus produce a health hazard. This eliminated high-boiling solvents such as dibutyl phthalate, benzyl benzoate, and *K-327* from further consideration. Chlorinated solvents were eliminated because it was desired to keep the health hazard as low as possible. The solvent must also be available in large quantities. Some solvents were ruled out because they gave poor emulsions with the emulsifiers tested.

Xylene was chosen as a solvent meeting all the requirements of the first all-purpose emulsion concentrate. It was sufficiently volatile to evaporate rapidly from cloth, was comparatively safe to use, and was available in large quantities. Grades from pure xylene to industrial xylene (solvent naphtha) could be used.

Experience has shown that the lighter-than-water feature, at one time thought desirable for an emulsion to be used as an anopheline larvicide, is not necessary. Solvents heavier than xylene may be used with equally good larvicidal results, except that much heavier solvents, such as those with densities over 1.0, do give poorer results. This question of keeping the concentrate lighter than water did, however, influence the early selection of xylene as the solvent. Subsequent work has shown that this was a good choice for both larvicidal and residual spray work.

PHYSICAL STABILITY TESTS.—A large number of emulsifiers and combinations of emulsifiers have been tested to determine their suitability for use in DDT emulsion concentrates. The emulsifiers have been grouped according to the physical stability of the emulsions obtained with them.

The results with emulsifiers, which with 1 per cent of DDT gave stable emulsions (little or no breaking in 24 hours) in distilled, hard, and sea water, are listed in table 1.

Triton X-100, *Triton X-155*, *Tween 80*, and *Span 20* plus *Tween 20* (equal parts) gave the most stable emulsions of the group. Any of the emulsifiers in table 1, however, would be considered satisfactory from the standpoint of stability.

Table 2 lists briefly results with those emulsifiers found to give stable emulsions in distilled water but unstable emulsions (show separation of oil phase) in either hard or sea water or both.

The emulsifiers forming unstable emulsions in distilled, hard, and sea water are as follows:

Alkanol B (sodium alkylnaphthalene sulfonate)
Alkanol SA (sodium alkylnaphthalene sulfonate)
Blendene (modified ammonium fatty acid compound)
Butyl *Cellosolve*
Carbitol phthalate
Diethylene glycol stearate
Ethylene glycol monolaurate
Intracol O (long-chain fatty acid basic amide)
Mannitan triricinoleate
Mulsor 3 CW (long-chain fatty acid ester of a polyglycol)
Propylene glycol monolaurate
Propylene glycol monostearate
Vatsol OS (isopropylnaphthalene sodium sulfonate)

Listed below are the emulsifiers which are too insoluble in xylene to be useful in the preparation of a suitable concentrate.

Alkanol S, flakes (sodium tetrahydronaphthalene sulfonate)
Ammonium laurate
Ammonyx T (alkyl dimethyl benzyl ammonium chloride)
Areskap 100 (sodium monosulfonate of monobutyl phenylphenol)
Detergent 92–Superfine paste (mixture of a sulfonated aliphatic amide, an aromatic sulfonic acid)
Diethylene glycol phthalate
Duponol C (sodium alkyl sulfates, principally lauryl)
Glyceryl monostearate
Glyceryl phthalate
Igepal CA Extra (alkyl aryl polyglycol ether)
Igepon AP (sodium salt of sulfonated ethyl oleate)
Mannitan glyceryl monolaurate
Orvus (sodium alkyl sulfates, principally lauryl)
Sodium naphthenate
Trestabit oil VU (sulfonated fatty acid)
Triton 720 (sodium salt of aryl alkyl polyether sulfonate
Triton 770 (sodium salt of aryl alkyl polyether sulfate
Triton 773 (sodium salt of aryl alkyl polyether sulfate)

Table 2.—Approximate physical stability of emulsions (1 per cent of DDT) showing little or no breaking in distilled water but marked breaking in hard or sea water after 24 hours. Prepared from concentrates containing 25 per cent of DDT, 10 per cent of emulsifier, and 65 per cent of xylene.

Emulsifier	Approximate Stability[1]		
	In Distilled Water	In Hard Water	In Sea Water
Aerosol CS-15	2	5	5
Aerosol ND-18	1	2	5
Aerosol ND-33	1	1	3
Alkanol WXN (sodium hydrocarbon sulfonate)	1	5	5
Ammonyx G (a mixture of higher alkyl dimethyl benzyl ammonium chloride)	2	5	4
Aresklene 400 (sodium sulfonate of dibutylphenylphenol)	1	5	5
Carbitol ricinoleate (diethylene glycol ethyl ether ricinoleate)	2	5	5
Cellosolve laurate (ethylene glycol ethyl ether laurate)	2	5	5
Dendrol (a miscible oil)	1	5	5
Diethyleneglycol monolaurate	1	3	5
Diethyleneglycol monooleate	1	5	5
Duponol G (an alkyl sulfate)	1	5	2
Emulphor AG-oil soluble (polyglycol ester)	1	5	5
Emulsifier L-32 (higher fatty ester of non-ionic tyep)	1	3	5
Emulsifier L-34A (higher fatty ester of non-ionic type)	1	1	5
Emulsifier L-45 (higher fatty ester of non-ionic type)	1	1	3
Emulsol X-20 or *Emcol X-20* (sulfated fatty acid glycol esters)	1	1	5
Glyceryl monooleate	1	3	5
Glyceryl monoricinoleate	1	5	5
Igepon T powder (sulfonated aliphatic amide)	1	5	5
Lupomin Extra (fatty acid amide salt)	1	2	5
Michul B (a sulphonated aliphatic ester)	1	5	5
Mulsor V-7 (non-ionic, polyglycerol type)	1	3	5
Mulsor 224 (non-ionic, polyglycol type)	1	1	5
Nacconol F (alkyl aryl sulfonate)	1	5	5
Nacconol NR (sodium alkyl aryl sulfonate)	1	5	5
Nacconol NRSF (sodium alkyl aryl sulfonate)	1	5	5
Nopco 1216 (sulfonated sperm oil)	1	2	5
Oranap (alkylnaphthalene sodium sulfonate)	1	5	5
Oranap P (alkylnaphthalene sodium sulfonate)	2	5	5
Propylene glycol monooleate	1	5	5
Sellogen AS Conc (alkyl aryl sulfonate)	2	4	5
Sellogen ASD Conc. (alkyl aryl sulfonate)	2	2	5
Sorbitol dioleate	1	5	5
Sorbitol distearate	1	5	5
Sorbitol laurate	1	5	5
Span 20 (sorbitan monolaurate)	1	3	5
Span 60 (sorbitan monostearate)	1	3	5
Span 80 (sorbitan monooleate)	1	5	5
Triton B-1596 (polyglyceride of a glyptal resin)	1	5	5
Vatsol OT (dioctyl sodium sulfosuccinate)	1	5	5
Wetsit Concentrated (alkylated aromatic sulfonate)	1	5	5
Aresklene 400 plus *B-1596* (equal parts)	1	5	5
Aresklene 400 plus *Duponol OS* (equal parts)	1	5	5
Triton X-100 plus: *Alkanol B* (equal parts)	1	1	5
Alkanol SA (equal parts)	1	1	5
Aresklene 400 (equal parts)	1	5	5
Span 30 (equal parts)	1	5	3
Vatsol OT (equal parts)	1	2	5

[1] Approximate stability was graded as follows: (1) No breaking in 24 hours (satisfactory); (2) no breaking in 2 hours, some breaking in 24 hours (moderately satisfactory); (3) some breaking in 2 hours, no marked increase in 24 horus; (4) some breaking in 2 hours, marked breaking in 24 hours; (5) marked breaking in 2 hours or less.

Triton K 60 (cetyl dimethyl benzyl ammonium chloride)

Triton W 30 (sodium salt of aryl alkyl ether sulfate)

Ultrawet (sodium sulfonate of petroleum hydrocarbon)

Triton X-100 was the first emulsifier tested that met the military requirements of the emulsion concentrate. The combination of *Span 20* and *Tween 20* was also found satisfactory early in the work.

PROPORTIONS OF DDT, EMULSIFIER, AND XYLENE.—In September 1943 the first emulsion concentrate was recommended for use by the armed forces. It comprised: 20 per cent of DDT, 20 per cent of *Triton X-100*, and 60 per cent of xylene. This concentrate formed very stable emulsions in water and was used with satisfactory results in many early large-scale tests. Recently it was found that the proportion of emulsifier could be reduced without interfering with the usefulness of the concentrate, and the following formula was recommended for military use: 25 per cent of DDT, 10 per cent of *Triton X-100*, and 65 per cent of xylene. This emulsion concentrate has been successfully used in a large number of laboratory and large-scale field tests as a mosquito larvicide, a residual spray for adult insects, and in louseproofing underwear. It has also been used in actual mosquito and fly control operations as well as in the control of other insects of medical importance.

In table 3 are given results of physical stability tests of emulsions made from concentrates containing a number of different proportions of DDT, *Triton X-100*, and xylene. At one time a 25/7/68 ratio was in use. Concentrates with low proportions of *Triton X-100* were found unstable in sea water. At low DDT concentrations they were also found unstable in distilled and hard water. It will be noted that the 25/10/65 ratio gives emulsions that were satisfactory from the standpoint of physical stability in all three types of water. Concentrates containing 30 per cent of DDT, besides forming less stable emulsions than the 25 per cent DDT concentrate, showed pronounced separation of DDT on chilling. Dilutions of the latter concentrate had the additional advantage of being more readily calculated than those of the 30 per cent concentrate.

SUMMARY AND CONCLUSIONS.—The requirements are given of a DDT emulsion concentrate for use in the control of insects affecting the armed forces. The method of testing the physical stability of emulsions to be used for this purpose is described. Results are given of physical stability tests of over 100 emulsifiers tested for this use.

Table 3.—Physical stability of emulsions (1 per cent of DDT) prepared from concentrates containing various proportions of DDT, *Triton X-100*, and xylene.

COMPOSITION OF CONCENTRATE			PERCENTAGE (BY VOLUME) OF CREAMY LAYER SEPARATED (TO TOP UNLESS NOTED)								
			In Distilled Water After—			In Hard Water After—			In Sea Water After—		
DDT Per Cent	*Triton X-100* Per Cent	Xylene Per Cent	15 Minutes	2 Hours	24 Hours	15 Minutes	2 Hours	24 Hours	15 Minutes	2 Hours	24 Hours
20	20	60	None	None	None	None	2–5	2–5	None	None	None
25	15	60	None	None	None	None	5+	5+	None	<2	<2
25	12.5	62.5	None	None	None	<2	5+	5+	None	2–5	2–5
25	10	65	None	None	None	<2	5+	5+	<2	5+	5+
25	5	70	<2	<2	2–5	<2	5+	5+	5+	5+	5+[1]
25	1	74	<2	2–5	5+	2–5	5+	5+	2–5[1]	2–5[2]	2–5[2]
30	15	55	None	<2[2]	<2[2]	None	2–5[2]	2–5[2]	None	None	<2[2]
30	10	60	None	<2[2]	<2[2]	None	5+[2]	5+[2]	None	2–5	5+
30	5	65	<2	<2[2]	<2[2]	<2	<2	2–5[2]	2–5	2–5	5+[2]
30	1	69	<2	2–5	2–5	<2	2–5	2–5	2–5[1]	2–5[2]	5+[2]

[1] Slight separation of oil phase.
[2] Marked separation of oil phase.
[3] Layer separated to bottom.

The emulsifier *Triton X-100* (an aralkyl polyether alcohol) was finally selected to be used in combination with xylene as the solvent. As a result of tests of numerous proportions of DDT, emulsifier, and solvent, a concentrate containing 25 per cent of DDT, 10 per cent of *Triton X-100*, and 65 per cent of xylene was recommended for military use. This formulation emulsifies, with a minimum amount of agitation, in distilled, hard, and sea water. It may be diluted to concentrations of from 0.1 to 10 per cent of DDT to form reasonably stable emulsions. In this manner it may be used in the control of adult mosquitoes, flies, and other insects; as a mosquito larvicide; and in the louseproofing of clothing.

The DDT emulsion concentrate has become one of the important DDT formulations. Its concentrated form, ease of preparation, and ready application to a wide variety of situations have made it especially valuable to the armed forces.

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DDT to Control Maggots in Latrines

B. V. TRAVIS[1] and R. M. BOHART[2,3], *U. S. Naval Medical Research Unit Number 2*

Populations of flies accompanied by serious outbreaks of dysentery, particularly during military operations, emphasize the necessity of controlling these insects. As control methods applicable to combat areas had not been developed prior to the war, personnel in charge of sanitation during combat frequently found it difficult or impossible to control flies. Two materials, sodium arsenite (*Penite*, a proprietary product containing 54 per cent active ingredient), Hering (1945a) and paradichlorobenzene (PDB), Anon. (1945c), have been shown to be useful for the control of maggots in latrines. Since the most common insecticide in the theaters of war was DDT, field tests were made in latrines on Okinawa (L+13 to L+60) to determine the efficacy of this chemical in the control of maggots.

MATERIALS AND PROCEDURE.—All test materials were applied to latrine pits by means of a 3-gallon cylindrical pressure sprayer (decontamination) equipped with the regular block-type spray nozzle. The DDT was used in the water emulsion form, and in kerosene or in diesel oil. The interior of the boxes and the walls of pits was treated, but most of the material was sprayed on the fecal mass. Tests were made in latrine pits very heavily infested with third and fourth stage maggots. The principal maggot concerned was *Chrysomyia megacephala* (Fab.). The latrines were the typical ones installed up to L+60 and none was adequately screened. The depth of pits varied from 6 inches to 8 feet. Only two of those tested were 8 feet deep, the average depth being 3 to 5 feet. The latrine boxes over most of the pits were so poorly constructed that the flies had easy access to the fecal material. In about half of the latrines, urinals which emptied into the pits made a wet fecal mass, an excellent fly-breeding medium.

Thirty-nine latrines with heavy fly breeding were treated with DDT during the tests. Observations were made at 24, 48, or 72 hours. Most of the second observations were made at the 48-hour interval, and the percentage kill was estimated from the number of live maggots.

RESULTS.—The data in table 1 show that DDT in the form of an emulsion, applied at the rate of 1 quart per seat hole and in concentrations of 2.5 to 5.0 per cent, adequately controlled maggots in pits where breeding was heavy. It was interesting to note that the DDT emulsion inactivated full-grown larvae in less than 12 hours; in fact, most of them were immobilized in less than an hour with a 5 per cent concentration. The oil solutions of DDT were effective at the rate of 1 quart of 4 to 5 per cent solution per seat hole. Usually, when oil solutions were applied, some maggots were alive 24 hours after treatment, but were dead at the 48- or 72-hour observation. Applications of 2 per cent DDT in diesel oil gave erratic results, and in one instance the surviving maggots were irritated and crawled out of the pit, some of which were able to pupate. About 200 men were using the 8-hole pit employed for the test. This pit was only 5 feet deep and maggots were nearly mature and exceptionally numerous.

The use of DDT in the form of an emulsion was discontinued when an explosion occurred in a 12-foot pit on routine treatment. The pit was treated in the morning with approximately 1 quart of 5 per cent emulsion per seat hole. The day had been quite warm. In the late afternoon, when all holes were in use, one of

[1] Lieutenant, H(S), U.S.N.R. On military leave from the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.

[2] Lieutenant-Commander H(S), U.S.N.R.

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the men struck a match which resulted in an explosion. The men were thrown from the latrine box and received severe flash burns. This was one of the only two 12-foot-deep pits seen on the island, and it was one of the few provided with a tight box. Subsequent tests proved that the xylene in the emulsion caused the explosion.

Tests were not made with other materials; however, during the course of the studies the following methods and materials were observed in use by various groups and none of them was giving adequate control: Diesel oil; diesel oil or kerosene plus daily burning; chlorinated lime (effective only if the fecal mass was kept completely covered); paradichlorobenzene (one-half of a No. 10 food can per hole every other day); and DDT dust scattered by hand. Olson & Dahms (1945b) report that 10 per cent DDT dust was ineffective in controlling house fly larvae in partly digested sewage sludge. They also report a low kill with treatment of the same material with 0.25 per cent emulsion. Data obtained in the latrine tests indicate that a much heavier application and a greater concentration of DDT, either in emulsion form or in an oil solution, is necessary for satisfactory fly maggot control than is used by many investigators.

Several groups placed their latrines on a routine weekly treatment of 1 quart of 5 per cent DDT in diesel oil or in kerosene per seat hole. Complete control was obtained except in the case of two 8-hole latrines that were heavily overloaded and not fly-tight. Some groups sprayed the pits with a small amount of the oil solutions daily with excellent results. In fact, this method gave the most sure and complete control of any method observed.

Table 1.— Results of tests on the control of maggots in latrines with DDT applied as an emulsion or as a solution in Diesel oil or kerosene (percentages of kill are estimated). Okinawa, 1945.

Emulsion of DDT				Oil Solution of DDT			
Quarts per Seat Hole	Per Cent of DDT	Per Cent Kill in— 24 Hours	48–72 Hours	Quarts per Seat Hole	Per Cent of DDT	Per Cent Kill in— 24 Hours	42–72 Hours
				Diesel oil			
1	5.0	100		1	4.0	100	
1	5.0	100		1	4.0	100	
1	5.0	95	100	1	4.0	100	
½	5.0	95	100	1	4.0	100	
1	2.5	100		1	4.0	99	100
1	2.5	100		1	4.0	95	100
1	2.5	100		1	2.0	99	100
1	2.5	100		1	2.0	95	100
1	2.5	90	100	1	2.0	95	100
1	2.5	90	100	1	2.0	95	100
				1	2.0	50	100
½	2.5	90	99	1	2.0	10	re-treated
½	2.5	50	100	1	0.0	75	75
1	1.0	99	—	1	0.0	50	re-treated
1	1.0	95	100				
				Kerosene			
1	1.0	95	100	1	5.0	100	
1	1.0	90	100	1	5.0	95	100
1	0.5	75	99	1	5.0	75	100
2	0.5	50	75	½	5.0	95	100
1	0.25	50	99	½	5.0	50	100
				½	5.0	25	95

Discussion.—Each of the insecticides, sodium arsenite, DDT, and PDB, has certain advantages and disadvantages that must be considered in choosing the best material for use in latrines. Sodium arsenite has such a high toxicity for man that it must be used with caution. On the other hand, it is the least bulky of the three, being prepared as a 54 per cent concentrate (*Penite*) which is diluted, 1 to 40 in the field, with any kind of water. This allows a large saving in shipping space, as 2 gallons, approximately 30 pounds in weight, will suffice for the treatment of latrines for 1000 men for 1 month. It is

effective under nearly all conditions found in latrines. While 32 pounds of DDT is enough to take care of latrines for 1000 men for 1 month, this substance requires more shipping space than does the equivalent amount of *Penite*.

The oil necessary for preparing the solutions makes DDT the most bulky of any material used for maggot control in latrines. However, the bulk of oil can be largely disregarded in combat areas because there is usually an excess of oil under these conditions. It is nearly equal to sodium arsenite in effectiveness under all conditions found in latrines. However, if used on mature maggots it does not always kill them soon enough to prevent their migration from the pit. It has a low toxicity for man and has another important advantage over *Penite*, namely, that of leaving a residue on the walls of the box and the pit which will kill adult flies.

When used in deep, dry, unventilated pits, PDB not only will kill maggots but will prevent flies from entering the pit. It has the disadvantages of not being completely effective in shallow, wet, ventilated pits. Also it requires considerable shipping space, since 200 pounds per 1000 men are needed each month to control flies and maggots.

Fly-breeding conditions in latrine pits vary so greatly that, regardless of the type of chemical used, the frequency and the quantity of treatment must be determined by periodic inspections. The figures given above for the amounts of chemicals necessary for controlling flies in latrines are minimum. Under certain unusual conditions, the interval between treatments must be decreased and the amount of insecticide used per seat hole must be increased. However, if sufficient latrine boxes and pits (8 seat holes per 100 men) are constructed properly (fly-tight and deep) and if treatment is started as soon as the pit is installed, control of flies and maggots is relatively simple. Any of the three chemicals can be expected to fail with a minimum dosage if the pits are teeming with full-grown maggots before treatment is initiated. All insecticides have failed to prevent breeding when applied weekly if the boxes were not fly-tight, if the pits were shallow (3 to 5 feet deep), and if more than the recommended number of men were using the latrines (up to 100 per seat hole has been observed). Small amounts of DDT or other insecticide sprayed daily into the pits has given the most sure and effective control in the tests.

SUMMARY.—A solution of DDT in a 4 to 5 per cent concentration in either Diesel oil or kerosene applied at the rate of 1 quart per seat hole once a week will control maggots in latrines that are built and used according to military specifications. Daily spraying of the fecal mass in quantities to total about 1 quart of insecticide per seat hole each week provides the most reliable control. DDT emulsions are not safe to use in latrines with deep pits and tight boxes because there is danger of explosion of the xylene vapor. DDT emulsions applied at a 5 per cent concentration can be used to control maggots not in enclosed spaces. The emulsion kills maggots much more rapidly than does the oil solutions and is, therefore, more satisfactory for this type of work.—9-25-46.

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DR. FRAENKEL TO LECTURE AT MINNESOTA

"Dr. G. Fraenkel, Lecturer in Physiology, Department of Zoology and Applied Entomology, Imperial College of Science and Technology, London, England, well-known for his work on insect nutrition, tropisms and other aspects of insect physiology, has been appointed Special Lecturer at the University of Minnesota for the Spring Quarter, 1947. Dr. Fraenkel will give a course in Insect Nutrition as a part of the graduate teaching program of the Division of Entomology and Economic Zoology.

Control of Fly Larvae in Simulated Pit Latrines and in Carcasses[1]

W. C. McDuffie,[2] Arthur W. Lindquist, and A. H. Madden,[3] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Blowflies, Calliphoridae, flesh flies, Sarcophagidae, and houseflies, *Musca domestica* L., assumed major importance as carriers of dysentery and as a source of annoyance to troops in combat areas of the Pacific war zone. The control of adult houseflies was investigated at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine during the early years of the war and DDT sprays were developed for this purpose (Lindquist *et al.* 1945 a and b). Because of the urgency of the problem, a study on the control of larvae was begun at Orlando early in 1945 at the request of the Office of the Surgeon General, United States Army. This project was divided into two phases (1) the control of flies and larvae in simulated pit latrines, and (2) the control of fly larvae in animal carcasses.

Field tests were initiated about the first of February in an effort to study control under outdoor conditions and to verify results already obtained by the authors in the laboratory. The early phase of the outdoor work was devoted to testing *p*-dichlorobenzene, which had been used successfully to control fly breeding in latrines in the central Pacific area by Maj. Franklin Sherman III, Sanitary Corps, United States Army. Tests also were conducted with *o*-dichlorobenzene, DDT, benzene hexachloride[4] acetylene tetrachloride, and a few tests with other materials. The primary objective was to test the immediate effectiveness of these and other materials against fly larvae, but such promising results were obtained with *p*-dichlorobenzene and *o*-dichlorobenzene that the majority of tests were made with these two materials.

Control of Larvae in Latrines.—For the latrine tests pits 18 to 24 inches deep with a bottom surface of 2 to 3 square feet were dug in sandy soil. In most cases an undiluted special rearing medium (oat hulls, alfalfa meal or bran) was used. This material is rather porous at first, but gradually settles into a fairly compact mass which probably simulates excrement fairly well. Ordinarily 6 to 8 inches of medium and 1000 or more half-grown to nearly mature housefly larvae were placed in each pit, but sometimes only 3 to 4 inches was used to test toxicity under the most favorable conditions. Treatments were applied to the surface of the media. Following treatment each pit was covered to give protection against wind and rain.

Tests with p-dichlorobenzene.—A series of exploratory tests showed that applications of 0.25 to 3.5 grams of granular *p*-dichlorobenzene per square foot caused only mild to moderately severe stupefaction of larvae. Activity and development were curtailed for 24 hours, but little or no mortality occurred. Similar dosages of marble-sized lumps were even less effective. Covering the *p*-dichlorobenzene with 1 to 3 inches of fresh medium 2 to 4 hours after application appeared to decrease its effectiveness, presumably because it retarded volatilization.

At dosages of 5 to 15 grams per square foot moderate to severe stupefaction of maturing larvae occurred, but these larvae gradually recovered and after 72 hours were practically normal. Furthermore, larvae exposed for 24 hours to these dosages and then placed in half-pint cartons of fresh media recovered completely in another 24 hours. Retreatment after 72 hours with dosages of 2.5 to 7.5 grams per square foot caused slight to rather high mortalities, but effective control was obtained only where the two treatments totaled 20 to 22.5 grams per square foot.

Satisfactory control was obtained with single applications of 20 to 25 grams of the granular *p*-dichlorobenzene per square foot in two out of four tests. In the two unsatisfactory tests retreatment 3 days

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] Captain, Sanitary Corps, Army of the United States.

[3] The writers acknowledge the assistance of E. F. Knipling, in charge, and H. A. Jones, Chemist, of the Orlando, Fla., laboratory. H. G. Wilson reared the housefly larvae and provided the carcasses used in these tests.

[4] Benzene hexachloride is the common term frequently applied to the chemical hexachlorocyclohexane.

later with 7.5 to 10 grams per square foot provided complete control.

Single applications of 10 to 25 grams per square foot of the lump *p*-dichlorobenzene caused slight to severe stupefaction and retarded development during the 5 to 6 days it persisted but volatilization apparently was too slow to produce a lethal concentration of gas. Thus the actual control was slight. It is believed that control with the lump material would necessitate slightly larger initial dosages, with retreatments at normal dosages to prevent further breeding.

The results of confirmatory tests under warmer weather conditions are shown in table 1. Records on mortality up to 96 hours after treatment are given. In general the data agree with those given above, although the over-all kill was higher owing to the effectiveness of the treatment against small to medium-size larvae.

Table 1.—Results of tests of light to heavy dosages of *p*-dichlorobenzene against housefly larvae in simulated pit latrines.

Dosage of *p*-Dichlorobenzene	Mortality After—	
	48 Hours	96 Hours
Grams Per Square Foot	*Per Cent*	*Per Cent*
Granular		
10	17	20
	12	18
	10	15
	0	10
15	45	48
	43	55
	10	40
	36	71
20	83	83
	64[1]	75
	100	100
	50	65
	20	40
30	95	100
Lump		
10	0	8
20	11	33
30	20	83

[1] Over 90 per cent mortality of small to medium-size larvae as compared with only 50 per cent mortality of large larvae.

In a few tests retreatment at the rate of 10 grams of the granular *p*-dichlorobenzene per square foot was made at the end of 96 hours. When the original treatment was 15 to 20 grams per square foot 95 to 100 per cent mortality resulted, but in one case, when the original treatment was only 10 grams per square foot, the kill was negligible. Thus it is concluded that control required about the same dosage as was necessary during cooler weather.

To gain more information on the mode of action against fly larvae, certain laboratory and field tests were made to determine the effectiveness of the material against various stages of flies. Preliminary laboratory tests indicated that *p*-dichlorobenzene was a highly effective ovicide, and that as little as 5 grams per square foot was sufficient to prevent hatching of all housefly eggs. This was confirmed in the field tests, which showed that fly control can be obtained by the application of small quantities of this material at regular intervals. Once larvae become established, however, the problem is more difficult and the initial dosage is greater.

Because there was no natural oviposition and breeding of houseflies in the pits, carcasses, which induce heavy blowfly breeding, were substituted for the bran medium in three tests. A freshly killed dog was placed in each pit, and a small hole was made in the cover to admit adult blowflies. The pits were treated immediately with 5, 10, and 15 grams of *p*-dichlorobenzene per square foot, and 3 days later with half the original dosage. At the time of the second treatment there were a few adults in each pit, but larvae were present only in the pit receiving the lightest dosage. In the other pits there was an abundance of unhatched eggs and dead newly hatched larvae. It was apparent that the treatments had reduced oviposition. Even in the lightly treated pit all larvae were newly hatched, indicating that this dosage was effective for 48 hours. Four days after retreatment the carcass in the lightly treated pit was heavily infested with small to medium-size larvae, whereas the other carcasses were uninfested and there were large numbers of unhatched eggs and dead adults in the pits. The carcasses were retreated, and in observations made 2 and 4 days later practically all the larvae in the lightly treated pit had been destroyed, none were evident in the heavily treated pit, and only a small number in the other pit. It was clear, therefore, that treatment every 3 to 4 days was sufficient to prevent blowfly breeding.

Tests with o-dichlorobenzene.—Preliminary tests in the laboratory showed that *o*-dichlorobenzene was very effective against housefly larvae both by contact and by fumigation. In a series of field tests dosages of 50 to 100 ml. per square foot gave complete kill of small, medium, and large larvae. In a few exploratory tests a high mortality resulted when additional larvae were placed in the pits 4 days after treatment. This indicates considerable residual toxicity in the media and suggests that control might be obtained with lighter dosages.

Variable results were obtained with 25 ml. per square foot, but in most cases mortality was complete or almost complete 2 to 4 days after treatment. The 24-hour kill was rarely high, but virtually all larvae were moribund and concentrated at the bottom and sides of the pits. The percentage recovery among such larvae was consistently low, although there were a few exceptions. The results obtained with 10 and 15 ml. of *o*-dichlorobenzene per square foot indicated that good control might be obtained at these dosages under certain conditions. However, it is doubtful whether such small quantities would be adequate in practice.

In two tests complete kill was obtained by following the initial dosages of 15 and 25 ml. per square foot with a retreatment on the third day of 15 ml. per square foot. This indicates that control of fly breeding can be obtained by applying this chemical in approximately the same amounts and at the same intervals as *p*-dichlorobenzene.

During these tests large numbers of housefly eggs were placed 2 to 3 inches below the surface of the media to determine the ovicidal effects of *o*-dichlorobenzene under such conditions. No hatching occurred. No dosages less than 10 ml. per square foot were applied to the media, but in the laboratory highly effective ovicidal action was obtained with 5 ml. It is indicated, therefore, that this chemical is about equal to *p*-dichlorobenzene as an ovicide.

A large series of tests was made with *p*-dichlorobenzene dissolved in an equal quantity of *o*-dichlorobenzene. There was no indication that the combination of materials was better than either one when used alone.

Comparative tests with fuel oil and o-dichlorobenzene, with and without p-dichlorobenzene or DDT.—A series of tests was conducted to compare the effectiveness of *p*-dichlorobenzene dissolved in fuel oil and in *o*-dichlorobenzene and of these solvents with and without DDT.

Fuel oil alone proved practically nontoxic, and fuel-oil solutions containing *p*-dichlorobenzene or DDT also gave poor kills in thick layers of medium (6 to 8 inches), even when applied in fairly large amounts. Satisfactory kill was obtained only when the quantity of liquid was sufficient to penetrate the entire medium; otherwise larvae merely migrated below the treated portion and continued normal activity. It was thus demonstrated that the toxicity of the oil was not enhanced by the DDT and that the effectiveness of *p*-dichlorobenzene was decreased in oil solutions. However, the residue of DDT in the media later caused almost complete mortality of emerging adults.

The immediate effectiveness of *o*-dichlorobenzene was neither deterred nor improved by the addition of *p*-dichlorobenzene or DDT. Small quantities of *o*-dichlorobenzene consistently gave high kills in 24 to 48 hours, with and without the extra ingredient.

Moderate to heavy applications of a 5 per cent DDT aqueous emulsion (made from a concentrate containing 25 per cent of DDT, 10 per cent of *Triton X-100* (polyethyleneglycol alkyl aryl ether), and 65 per cent of xylene) were about as ineffective as DDT in fuel oil when applied to a thick layer of medium. In these thick layers the larvae migrated below the treated portion and remained unaffected, but the DDT residue killed large numbers of adults emerging 8 to 10 days after the emulsion was applied.

Comparative effectiveness of p-dichlorobenzene and DDT.—A number of tests were conducted to compare the effectiveness of a larvicidal treatment with *p*-dichlorobenzene and of residual DDT sprays against the emerging adults. In these tests cages were placed over the pits at the proper time to collect all adults emerging from the media, and 24 hours later they were examined to determine the survival. Results of a representative series of such tests are summarized

in table 2. Three heavy dosages of *p*-dichlorobenzene killed practically all the larvae. DDT, on the contrary, gave poor larval kill but destroyed most of the emerging adults.

From the results of these tests and others conducted in the laboratory, it can be concluded that DDT is of little value for the immediate control of fly larvae. It should be pointed out, however, that *p*-dichlorobenzene, *o*-dichlorobenzene, and perhaps other materials are effective larvicides only under certain conditions, and may not be satisfactory for control of fly breeding in many important situations.

Table 2.—Effect of *p*-dichlorobenzene and DDT treatments of simulated pitlatrines on emergence and survival of adult flies.

Material	Amount per Square Foot	Number of Flies			
		Collected	Living in 24 Hours	Dead in 24 Hours	Dead on Media in Pit
p-Dichlorobenzene	60 gm.[1]	3	3	0	0
DDT 5%:					
Aqueous emulsion[2]	16 ml.	370	285	85	1,560
In fuel oil	16 ml.	60	41	19	1,599
In pyrophyllite	16 gm.	498	493	5	1,394
Check (untreated)		8,619	8,619	0	0

[1] 3 applications.
[2] Made from a concentrate consisting of 25 per cent of DDT, 10 per cent of *Triton X-100*, and 65 per cent of xylene.

In such cases, or where breeding is too general to permit treatment of most of the breeding areas, a DDT residual spray directed against adults is a necessary adjunct to control. As it is unlikely that either method will give satisfactory control at all times, control measures should be directed toward the elimination of both larvae and adults.

CONTROL OF LARVAE IN CARCASSES.—The animals (dogs) used in these studies were killed by carbon monoxide fumigation and exposed in the field for natural infestations to occur. Ordinarily heavy infestations developed in 24 hours, and the animals were suitable for spraying in 48 to 72 hours.

Infestation Treatment of Carcasses.—The test materials were applied with a decontamination-type sprayer, or with a sprinkler, in amounts varying with the size of the animal. In most of the tests a rate of 1 pint of spray to a 25- to 40-pound animal was maintained, but where very dilute water emulsions were involved the rate was increased to 1.5 to 2 pints. The amount of the active ingredient in these solutions was so small that dosages could be increased without violating the practical consideration of economy of materials.

In applying sprays care was taken to cover the carcass and the larva-infested ground beneath. Half or more of the larvae may be underneath the carcass, and the soil must be raked in order to expose them to the spray. Considerably more liquid is required to treat a carcass and the ground underneath than to treat the carcass alone. Furthermore, the quantity necessary to achieve effective control may vary with the size and abundance of the larvae, the condition of the carcass, and the area to be covered. There may be differences also with respect to the species of flies.

In early tests DDT in oil solutions and in water emulsions killed very few blowfly larvae and the remainder continued their development and destroyed the carcass. Whether the contact with or ingestion of DDT resulted in belated death after pupation or upon emergence as adults was not determined. Tests were therefore undertaken with a wide variety of materials (undiluted) in oil solutions and in water emulsions. Results obtained in tests with the most promising of these materials are summarized in table 3.

Reports have indicated that satisfactory control of breeding by the fly *Chrysomyia megacephala* (F.) in cadavers during and following battle has been accomplished in many instances by the liberal application of dilute (0.6 per cent) sodium arsenite-water solutions to infested bodies and surroundings. Tests with sodium arsenite against larval in-

Table 3.—Results of tests in which heavily infested dog carcasses were sprayed with various chemicals. Dosage, 1 pint per 25- to 40-pound carcass.

Material	Number of Tests	Control in 24 Hours	
		Range	Average
		Per Cent	*Per Cent*
Sodium arsenite			
0.6%	6	10–40	25
1.0%	2	10–90	50
2.5%	3	90–100	97
5.0%	3	98–100	99
10.0%	1	—	100
o-Dichlorobenzene:			
Undiluted	12	90–100	97.5
20% in No. 2 fuel oil	4	80–99	92
10% emulsion	1	—	35
DDT 5% in *o*-dichlorobenzene	7	90–100	97
Nopco 1216 (sulfonated sperm oil) 5% in *o*-dichlorobenzene	3	75–98	88
Acetylene tetrachloride in No. 2 fuel oil:			
5%	1	—	50
10%	1	—	98
20%	1	—	85
Undiluted	3	75–100	91
Benzene hexachloride (10–12% gamma isomer)			
2% in No. 2 fuel oil	2	60–80	70
5% in xylene 20% plus kerosene 80%	5	97–100	99
Benzene-*Triton X-100* emulsion	2	10–25	17.5
Benzene hexachloride-*Triton X-100* emulsion:			
0.25%	3	25–98	74
0.5%	6	50–98	87
1.0%	6	90–99	97
2.5%	2	98–100	99
5.0%	2	—	100
DDT (2.5%)-benzene-*Triton X-100* emulsion	1	—	25
Thanite (chiefly isobornyl thiocyanoacetate):			
10% in *Triton X-100* (emulsion)	3	95–98	97
20% in No. 2 fuel oil	2	85–97	91

festations, primarily of *Cochliomyia macellaria* (F.), in animal carcasses have confirmed the effectiveness of this material when used in strengths of 2.5 per cent or more in water; weaker solutions proved relatively ineffective at the minimum dosages used in comparative tests. Solutions of sodium arsenite did not provide immediate immobilization or kill of larvae on contact, but within 24 hours virtually all the larvae succumbed from ingestion of the material.

Two of the chemicals tested, *o*-dichlorobenzene and acetylene tetrachloride, were suggested by the Chemical Warfare Service. Both these chemicals provided instant immobilization of larvae, and minimum amounts consistently gave near-perfect to perfect control when thoroughly applied to a carcass. Both materials remained highly effective when diluted 1 to 4 with No. 2 fuel oil. Acetylene tetrachloride was effective when diluted 1 to 9, but *o*-dichlorobenzene was not tested at this dilution. However, in several tests 10 per cent of *o*-dichlorobenzene in emulsion form proved ineffective. A suitable emulsion of acetylene tetrachloride was not developed.

Both *o*-dichlorobenzene and acetylene tetrachloride possess qualities of a good larvicide; they immobilize larvae quickly and are effective in relatively small quantities, either undiluted or in oil solutions. On the other hand, they have the disadvantage that large supplies of both the chemicals and the oil would be necessary for extensive control work. Moreover, the fumes of acetylene tetrachloride are said to be highly toxic, and *o*-dichlorobenzene is irritating to the skin. Dilution with oil, however, may reduce these dangers to a great extent.

The British had reported good results with benzene hexachloride against fly larvae. Five per cent of this chemical in oil solutions gave good kills on carcasses in Florida. Since benzene has long been used for destroying larvae of *Cochliomyia americana* C. & P. in wounds of animals, it was thought that an emulsion containing this solvent and benzene hexachloride should be tried. An emulsion concentrate composed of 20 per cent of benzene hexachloride, 68 per cent of benzene, and 12 per cent of *Triton X-100* was developed, and in field tests it proved consistently effective against blowfly larvae. Dilutions of 1 to 4 and 1 to 9 with fresh water provided instant cessation of movement and extremely high kills of larvae. Highly

effective control was also obtained with dilutions of 1 to 19 and 1 to 39, but larvae were not immobilized so swiftly. This concentrate makes a satisfactory emulsion in fresh water after brief, vigorous agitation. It will not emulsify satisfactorily in sea water, but it is believed that this can be overcome by the use of a more powerful emulsifying agent or larger amounts of *Triton X-100*.

A concentrate containing the same quantity of benzene and *Triton X-100*, but without benzene hexachloride, proved ineffective at a dilution of 1 to 7. When larvae were liberally contacted with the spray, movement ceased or was reduced, but the majority recovered. One test with a similar concentrate containing 20 per cent of DDT gave equally unsatisfactory results when diluted 1 to 7. These comparative tests indicated that benzene hexachloride was an essential ingredient in the benzene emulsions. On the other hand, 20 per cent of benzene hexachloride in such solvents as *Solvesso No. 3* (aromatic petroleum fraction, medium boiling range), *PD-544-C* (an aromatic petroleum fraction), xylene, *o*-dichlorobenzene, and *K-327* (coal-tar fraction, chiefly methylnaphthalenes) proved less effective in immobilizing and killing larvae than the benzene hexachloride-benzene formula.

The benzene hexachloride-benzene-*Triton X-100* concentrate possesses many advantages for the control of blowfly breeding. It can be diluted with water and applied in whatever amounts may be necessary to achieve effective control without upsetting the economy of materials. For example, 50 gallons of the concentrate will make 1000 gallons of 1-per cent benzene hexachloride-water emulsion, which should be ample to treat and control fly larvae in 500 to 1000 cadavers. The supply and distribution of the concentrate could be handled with a minimum of effort, and control work could be prosecuted promptly wherever a field water supply was readily available.

Preinfestation Treatment of Carcasses.—DDT in oil solutions and in water emulsions proved ineffective against established infestations of blowfly larvae, but when applied shortly after the death of test animals it delayed and minimized the infestation. During cool weather carcasses sprayed with DDT did not develop infestations for 8 to 10 days. The carcasses became bloated, produced an extremely disagreeable odor, and attraced myriads of adult flies, many of which became affected and died from contact with DDT. In hot weather similar applications of DDT in oil, in emulsions, and in *o*-dichlorobenzene prevented exterior infestation for 4 to 7 days and reduced the infestation developing thereafter. Benzene hexachloride in several solvents and *o*-dichlorobenzene (without DDT) were similarily effective.

In warm weather rapid bloating tended to force body fluids from the mouth and anus, thus forming untreated areas upon which flies fed and freely oviposited, and larval infestations usually developed in 2 or 3 days. In spite of this vulnerable point, preinfestation treatments are highly desirable, because the infestation is localized for a short time and minimized on the whole. Furthermore, the DDT or benzene hexachloride residue on the carcass is highly effective against adult flies alighting thereon.

To substantiate the effectiveness of pretreatment residue, flies were collected from one untreated and two DDT-treated carcasses. Fly traps were placed over each carcass and adults collected as they attempted to escape through the open top of the trap. Collections were made over periods of 15 to 60 minutes.

Data showed that 81 to 85 per cent of adult flies, *Cochliomyia macellaria* and *Musca domestica*, collected from a carcass treated with 1 pint of a 5 per cent DDT emulsion died in 24 hours, as compared with only 2 to 12 per cent of the flies from the untreated check. When the area within 1 foot of the carcass was treated lightly with a portion of a similar concentration, the kill was 90 to 95 per cent, or 5 to 10 per cent greater than that resulting from treatment of the carcass alone. No doubt some of the trapped flies were caught soon after they came to the carcass, and it is believed that practically 100 per cent mortality will result with flies in nature which have continuous access to carcasses treated with DDT. Thus, the inclusion of DDT treatments of carcasses or cadavers would appear to be highly advantageous. The residual effectiveness of benzene hexachloride under similar conditions has not been accurately

measured, but indications are that it too is highly effective against adult flies.

In a few tests *Thanite* showed considerable promise against blowfly larvae. A mixture of 20 per cent of *Thanite* and 80 per cent of fuel oil gave remarkably good kills, as did 10 per cent of *Thanite* in emulsion form, with and without benzene hexachloride. Neither of these mixtures caused immediate immobilization of larvae, but their effectiveness was apparent in 1 to 2 hours.

Tests with cyclohexanone, *Velsicol NR-70* (chiefly tetramethylnaphthalene), thialdine, D-D emulsion (mixture of dichloropropane and dichloropropylene), and several other materials yielded good to poor kills, and none was equal to the more promising ones discussed in detail above.

SUMMARY.—*p*-Dichlorobenzene and *o*-dichlorobenzene were tested extensively in simulated pit latrines containing housefly larvae. Both these chemicals gave good kill of larvae when applied to the surface of the medium at the rate of 10 to 20 grams of *p*-dichlorobenzene and 15 to 25 ml. of *o*-dichlorobenzene per square foot. Smaller dosages were satisfactory if followed by retreatment in 2 to 4 days.

Both chemicals are also highly effective against fly eggs. As little as 5 grams of *p*-dichlorobenzene or 5 ml. of *o*-dichlorobenzene have prevented hatching of housefly eggs.

Fuel oil alone or containing various amounts of *p*-dichlorobenzene did not give good results. Five per cent of DDT in fuel oil also was a poor larvicide. The addition of DDT to any solvent, however, provided an effective residual treatment for emerging adults, and even though larvae were not killed the production of adult flies was materially reduced.

o-Dichlorobenzene, acetylene tetrachloride, benzene hexachloride and *Thanite* (chiefly isobornyl thiocyanoacetate), showed promising results when used to destroy blowfly larvae in carcasses. *o*-Dichlorobenzene and acetylene tetrachloride, when sprayed at the rate of 1 pint per 25- to 40-pound carcass, killed the larvae almost instantly. These chemicals were highly effective when diluted 1 to 4 with fuel oil.

An emulsion concentrate consisting of 20 per cent of benzene hexachloride, 68 per cent of benzene, and 12 per cent of *Triton X-100* (polyethyleneglycol alkyl aryl ether) proved very effective in field tests. Dilutions of 1 to 4 and 1 to 9 with fresh water caused almost instant cessation of movement of larvae and high kills when used at 1 pint per animal. Highly effective control was obtained with dilutions of 1 to 39, but the larvae were not swiftly immobilized. Other solvents, such as *Solvesso No. 3* (aromatic petroleum fraction, medium boiling range). *PD-544-C* (aromatic petroleum fraction), and xylene proved less effective in immobilizing the larvae rapidly.

A mixture of 20 per cent of *Thanite* and fuel oil gave remarkably good kills of blowfly larvae, although its action was somewhat slow. It is highly desirable to add 5 per cent of DDT to all the larvicides, except perhaps benzene hexachloride, because of the effectiveness of the residue on adult flies that visit the carcass.—7-21-46.

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DR. JOHN DEAL NOW IN SHANGHAI

Dr. John Deal, formerly of the Extension Service of Pennsylvania State College, is Advisor on entomological problems to the Chinese National Government. Mr. Deal was sent to China in January 1946 by the United National Relief and Rehabilitation Administration for work with the China Mission. He may be addressed through UNRRA, Embankment Building, Soochow Road, Shanghai, China. In December 1946, Mr. Dean Echkoff, who recently left a position in private industry, was engaged to work with the same mission and is now in China.

PAUL KNIGHT

DDT Used to Control Flies in Manila

JAMES T. GRIFFITHS, JR.[1,2]

There has been a great deal of discussion about the possible values of spraying large acreages with organic insecticides in order to eliminate a major portion of the flies and mosquitoes. It is well recognized that such insect population decreases over a period of weeks would be beneficial for the maintenance of public health by controlling some insect borne diseases. Lindquist *et al.* (1945) reported on the effectiveness of DDT when used against adult mosquitoes, but opportunites to observe extensive and repeated treatments have been limited. The data reported here were obtained between March and August 1945 during airplane spray operations in Manila, Philippine Islands. Since the author had other duties at that time, observation were, on occasion, necessarily incomplete, and his transfer to a new headquarters required that the work be terminated early in August. Nevertheless, the changes in adult fly populations which were noted prior to and following both airplane and ground power spraying made it possible to make suggestions concerning spray schedule intervals which would appear to be efficacious where prolonged periods of fly reduction are desired.

Manila was occupied by American troops during the first week of February, 1945. General sanitation was very poor at that time. Under the Japanese, garbage collection and pail latrine systems had become practically non-existent. At the time of the arrival of the United States troops, indiscriminate faeces deposition was a common practice, and garbage was found in piles which, in some cases, were so large as actually to form road blocks. Flies swarmed in abundance throughout the city. As soon as a section of the city was liberated from Japanese control, a general clean-up campaign was instituted. This report is a study of the effectiveness of DDT spraying as performed both by airplane and by power equipment in areas north of the Pasig River which were known locally as San Nicolas, Santa Cruz, and Tondo.

AIRPLANE SPRAYING.—In order to ascertain the relative abundance of flies before and after spraying, a method involving the use of fly baits and counting the number of flies attracted per minute was decided upon. Three series of 15 stations each were established in different parts of the city: Series I in San Nicolas, Series II in Santa Cruz, and Series III in Tondo. Each group of stations was scattered over an area of 10 to 25 city blocks. These three sections of the city contained the major portion of the population of North Manila.

The bait consisted of one slice of white bread which was sprinkled with sugar and moistened with about one tablespoon of vinegar. The bait was placed in a china bowl and enough water added to render the slice moist. It was impossible to check each series every day, but counts were made as often as possible. A given station was checked at approximately the same time of day, both in the morning and afternoon. The bowl was placed as nearly as possible in the same place for each count. It was allowed to remain in place for 1 minute and then all flies which had gathered were brushed away. Following this, for each of 5 successive minutes, the flies which settled on either the bowl or bait were counted. At the end of each minute all flies were brushed away and a new count started. Thus, for each station 10 counts were made during the course of the day and a figure of average flies attracted per minute was obtained.

The San Nicolas area included part of Manila's Chinatown. It was very heavily populated and houses were built close together with little or no yard space. In February and early March, large piles of garbage and human faeces were scattered along the streets and in the gutters. Fly counts were started in this area on March 15, 1945. By this date, many of the largest piles of refuse had been removed. However, much garbage remained, and it was not until the last of May that garbage and faeces disposal was at all satisfactory.

[1] Formerly with the United States Army. Now employed by the Florida Citrus Experiment Station.

[2] The author wishes to express his appreciation for the cooperation of Lt. (j.g.) Thomas Snipes U.S.N.R. and Ensign H. L. Straube U.S.N.R. without whose assistance much of this work would have been impossible.

The Santa Cruz sector of Manila was inhabited largely by native Filipino stock. Although houses were often crowded together, yards usually present, and at the time of American occupation, better sanitation prevailed than in San Nicolas. Soil pollution and piles of garbage were evident throughout the observation period but, in general, it was a relatively clean area, judged by Manila standards. Fly counts were first made in this sector of the city on April 9.

The Tondo area was the dirtiest of the three experimental sectors. It was inhabited largely by poor class Filipinos and Chinese. The area was low and general sanitation was very poor. Fly counts were started in this sector on May 1. In June and July, this series was also used to test the efficacy of a ground power sprayer.

Fly counts were made between March 15 and August 4. During that interval, the entire city was sprayed four times by airplanes: April 13–16, May 5–8, June 4–7, and June 22–27. From two to five C-47's, flying in formation, dispensed sprays simultaneously over the city at a rate of approximately one half pound of DDT per acre. The sprays were applied between 7 and 10 o'clock in the morning. At this time, wind was usually at a minimum and the solutions were allowed to settle without a general dissipation due to air movements. The airplanes flew almost at housetop level, and as the spray, composed of DDT in diesel oil, fell, it was dense enough so that automobiles were forced to use windshield wipers when driving through the mist. A description of the equipment on these planes has been previously reported by McMahon (1945).

Figure 1 indicates graphically the actual fly counts (average number of flies attracted per minute) for all three series from April 9 to July 7. Around March 15 to 20, counts in San Nicolas averaged between 20 and 25 flies per minute. These decreased until, on the 3 days before spraying, they averaged only seven or eight flies per minute. During late February and March, an intensive clean-up campaign had markedly reduced the accumulated garbage and faeces in this area. With this elimination of refuse, it appeared that fly breeding was decreased. On the basis of similar reports from other parts of Manila, it is believed that the

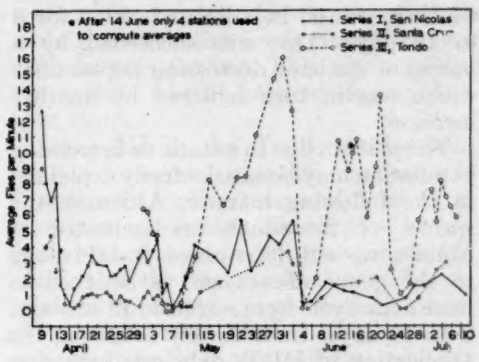

FIG. 1.—Actual fluctuations of fly populations.

improvement in sanitation which was made in late February and March was responsible for a general decrease in flies throughout the city. Although the period from July 7 to August 4 is not included in figure 1, counts were continued for all three series to that date. Populations during the first few days of August were essentially the same as those around July 7. As noted in figure 1, these would not differ significantly from those of late April.

During the June 24 spraying, only half as much DDT as usual was used in the San Nicolas area. Of course, one application is inconclusive, but this treatment appeared to be less effective than usual.

In figure 1, the initial effects of airplane spraying of DDT are readily to be observed. In almost all instances there was a reduction in adult populations to a point which approached zero. Series I and III were sprayed twice during a spray period on three occasions. This occurred for Series I on April 13 and 15 and again on May 5 and 7. For Series III, it was on June 23 and 26. This resulted in greater fly kill and a prolongation of the period when adult populations were low. Certain variables, due to such factors as changes in humidity and temperatures, the relative dampness of the soil, the amount of wind, the amount of shade, the time of day, etc. could not all be adequately controlled. The proximity of new piles of garbage or faeces, or the recent removal of such piles undoubtedly influenced fly counts in local areas. However, in spite of the irregularities in fly counts due to these uncontrollable factors, certain trends were evident. The initial reduction in flies was followed by a rising population

which increased in a linear fashion for 8 to 10 days. This was succeeded by a period of static or decreasing populations which was in turn followed by another increase.

The plateau due to a static or decreasing population may be satisfactorily explained in the following manner. Although the species of fly which predominated in Manila was not determined, it did belong to the genus *Musca* and is believed to have a life cycle from egg to adult of about 8 to 12 days. Immediately following the application of DDT, only relatively few flies remained in an area. These deposited only a fraction of the eggs per day which had been produced prior to spraying. Thus, for 8 to 10 days after treatment, the rate of increase in the number of flies counted was directly proportional to the daily egg deposit prior to spraying. However, after about 10 days, adult emergence was reduced to a level commensurate with the eggs deposited for the few days after spraying, and a plateau became evident. Fourteen to 18 days after spraying, another increase was observed. This appeared to be due to the emergence of flies from eggs which had been deposited shortly after the DDT was applied.

Since airplane application of DDT is able initially to reduce adult fly populations, the next problem is to consider the prolonged or semi-permanent effects of DDT spraying. It would be desirable to spray in such a manner that fly populations would remain low for a relatively long period of time. In order to do this, there must be a carry-over from one spray period to another. The important consideration appears to be the time interval between effective treatments. As noted above, the peak population for the 14 days following DDT applications was attained after about 8 to 10 days. Therefore, if sprayings were performed again within 10 days, a maximum population would be killed before the females had time to lay an appreciable number of eggs. If this situation were attained, fly populations would be expected to increase more slowly, and they would reach a lower total during a given period following each successive spraying. This condition was not obtained by spraying with airplanes at approximately monthly intervals. Although Series III was not checked in April, the third and fourth sprayings in June were succeeded by more rapid increases than in May. Similarly, Series II did not show slower increases after the last spraying. The third and fourth sprayings in Series I were followed by increases which were slower than those following the first and second sprayings. At this time, garbage collection and general sanitation were markedly improved in the San Nicolas sector. This was a local condition, since the improvement was less well marked over other parts of the city. It is believed by the author that this improvement in sanitation rather than airplane spraying was responsible for the decreased fly populations and the consequent slower increase in population in San Nicolas.

Theoretically, the refuse in any area would be able to maintain only a certain maximum fly population. When this maximum was attained, fly densities would be expected to remain constant as long as the amount of breeding medium remained approximately the same. Therefore, fly populations would be expected to increase following a spray application until the area's ecological maximum were attained. It logically follows that the slower that rate of increase following a treatment, the longer the time to reach the maximum and the longer the period of reduced fly infestation. As noted above, the daily rate of increase following a given treatment was due to the rate at which eggs were deposited prior to spraying. If successive treatments had cumulative effects, it would be expected that the rate of recovery following each successive spray would be less. Thus, if treatments were close enough together, flies would have insufficient time to lay eggs, and fewer larvae would be produced. Consequently, adult fly populations would increase more slowly following each successive application, and they would require a longer period to attain the area maximum. Reference to figure 1 shows that populations generally tended to return to the pre-spray level within two to three weeks. Observations of August 4 did not show further increase in population after that length of time. It appears, therefore, that airplane spraying, as performed in Manila, markedly reduced fly infestations initially, but that there was little or no

carry-over from one treatment to the next. It may be concluded, therefore, that airplane spraying at 3 to 4 week intervals with DDT in diesel oil at the rate of 8 ounces of DDT per acre is a method which will initially reduce fly populations almost to zero, but which will not maintain reduced fly infestations.

POWER SPRAYING. In order to find a spray schedule which would result in slower increasing populations after successive treatments and, thus, longer periods of reduced fly infestation, two methods were considered. One of these was to apply insecticide on either successive or on alternate days for a period of approximately 2 weeks. Theoretically, spraying at these intervals would result in a situation where flies were being killed almost as soon as they emerged. Since no new eggs were being deposited, it appeared to be possible to reduce flies and fly breeding to a minimum for a considerable period of time. However, as it would be impossible completely to eliminate all flies, it was anticipated that ultimately populations would reach the area maximum within a few weeks. The other method considered was to spray at approximately 10-day intervals and thus reduce the infestations as they attained initial peaks following any given treatment.

Airplanes were not available to test either method of application. The mechanical difficulties involved in spraying large areas every day made the first method seem impractical. It was decided, therefore, to try out the latter method by using ground power equipment in a limited area. This also offered an opportunity to test the efficacy of such an apparatus for adult fly control. A CWS decontaminator M-4 400 gallon sprayer mounted on a 2.5 ton truck chassis was used. This sprayer had a pump capacity of 35 gallons per minute. A mist of DDT in diesel oil could be thrown into the air to such a height that it readily drifted over two-story buildings. Checks on drift indicated that with a light breeze, particles easily carried more than a block. When applying the treatment, the truck, with nozzles directed into the air, was driven slowly up each street in the test area. An uneven, but complete coverage was obtained with heaviest concentrations of insecticide settling nearest to the spray truck. The treatments were applied at midnight when there was usually only a light breeze blowing. This also avoided the crowds which gathered during daylight hours.

Series III in the Tondo section was selected for experimentation. Stations 1 to 4 were used as controls, and 5 to 15 as experimental stations. This type of breakdown was necessitated by the geographic location of the various stations. The experimental stations were scattered over about eight city blocks. Because this area was small, it was anticipated that the migration of flies from adjacent uncontrolled areas might present a problem which would prevent an accurate analysis of the population trends. However, this did not prove to be the case. Possibly this factor was minimized by the fact that all adjacent areas were dirty and quite attractive to flies. Thus, there may have been very little inducement, at least from a food and oviposition standpoint, for migration. One apparent migration followed the July 17 spraying and is discussed below.

The first power spraying was on June 15. Table 1 shows the dates on which the area was sprayed with either airplane or power equipment. Higher concentrations of DDT were often used in the power spraying, and this factor must be considered in evaluating results. All treatments except that on July 10 consisted of DDT in diesel oil. The July 10 application was a DDT water emulsion.

Table 1.—Spray schedule in series III.

TYPE OF APPLICATION	LBS. OF DDT PER ACRE	DATE OF APPLICATION
Airplane	0.5	June 4
Ground	1.1	June 15
Airplane	0.5	June 22
Ground	1.7	July 3
Ground	2.5[1]	July 10
Ground	0.2	July 17
Ground	1.5	July 24

[1] DDT-water-xylene emulsion.

Figure 2 shows the results of airplane and power spraying on the control and experimental series from May 6, immediately after airplane spraying, to August 4. It will be noted that, up to the time of the first power spraying on June 15, the two series followed essentially the same population trends. Therefore, it was

concluded that the two series represented comparable populations and that the difference between them after June 15 represented the degree of control obtained by frequent ground power spraying. All treatments effectively reduced fly densities. Of the various concentrations used, the least effective was the water emulsion. This was true in spite of the fact that it was applied at a heavier concentration than any of the diesel oil treatments. On July 17, only 0.2 lb. of DDT was used per acre, but the populations were effectively

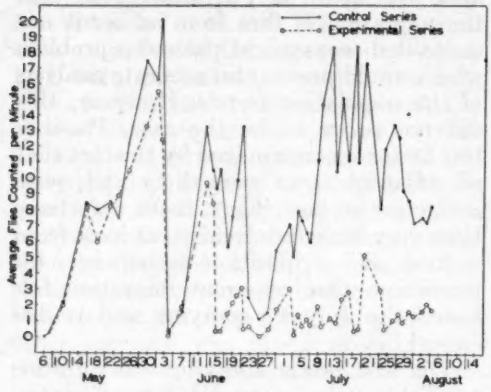

FIG. 2.—Effect of ground power spraying on adult fly population

reduced. In spite of this, on July 19 an extremely heavy population was found. Although migration from adjacent areas had not been a disturbing factor previously, it appeared to be the only satisfactory explanation for the unusual increase experienced here. Studies of rates of increase for each individual station did not yield conclusive evidence, but they appeared to support the migration theory since populations of stations at the margins tended to increase more rapidly than those in the center of the experimental area.

The final power spraying was done on July 24. If the July 17 spray is not considered, it may be noted that, in general, population increases tended to become slower with successive treatments. The last application was followed by the slowest rate of increase observed in the tests. This was true in spite of the increased populations which had occurred after the previous spray application. Thus, it appeared that spraying at 10 day intervals did result in slower increases following successive applications. However, as noted above, it was not possible to check the duration of reduced populations. In any case, the four power applications in July which followed the last airplane spray in late June, materially reduced the fly infestation in the experimental area as compared with that in the control area (see figure 2). Although additional work is necessary in order to substantiate the trends indicated here, it is believed that treatments at intervals of about 10 days would offer an opportunity for effectively maintaining low populations during the period of application and for some time following the final treatment. It is believed by the author that spraying at approximately 10-day intervals rather than daily would offer a more efficient use of DDT or any similar material. The duration of low infestation would probably be about the same following both programs, but the former would give reduced fly populations during the much longer period of spray application.

EFFECTS ON MOSQUITO POPULATIONS.—Some observations were made on the effect of DDT on both larval and adult mosquito populations. *Culex quinquefasciatus* made up more than 95 per cent of the mosquito infestation in Manila during the observation period. Larvae were found in great abundance in street gutters, tin cans, wells, etc. The degree of larvicidal action was found to be highly irregular after airplane spraying. At times mortality was as high as 95 to 98 per cent, but within the same block, other places showed little or no reduction in infestation. No explanation for this can be offered at this time. However, it should be noted, that flies were observed to die in the immediate vicinity of gutters where no mosquito control was obtained. The use of one human baited trap indicated that although adult mosquitoes were reduced in numbers for from 1 to 3 days, little effect could be noted thereafter. Mosquitoes, both larvae and adults, were present in large numbers throughout the observation period.

SUMMARY AND CONCLUSIONS.—1. The city of Manila was sprayed by airplane with DDT in diesel oil four times during the period from April through June 1945. The insecticide was applied at the rate of approximately one half pound per acre. Observations on adult fly populations indicated that spraying reduced the in-

festations to a level which approached zero. However, spray intervals of 3 to 4 weeks were too long to produce cumulative effects.

2. A ground power spray machine was used in a limited area to dispense DDT at approximately 10-day intervals. This method was effective in reducing fly populations. The carry-over due to successive applications was evidenced by a trend of more slowly increasing populations following each succeeding treatment.

3. Observations of mosquito reduction were inconclusive.

4. On the basis of these observations, it is suggested that the application of DDT at approximately 10-day intervals would be a satisfactory method for maintaining low adult fly populations both during treatment and for a period of time thereafter.

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Chilo loftini in California, Arizona, and Mexico

H. T. OSBORN and GRACE R. PHILLIPS, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Chilo loftini Dyar, a sugarcane pest of economic importance in western Mexico, was reported for the first time from California on November 28, 1944. In connection with the Special Survey in the General Vicinity of Ports of Entry the larvae were found boring in sugarcane and rice stubble in Imperial County near Calexico, located in the irrigated section of the Imperial Valley adjacent to the Mexican border. Immature forms, together with reared adults from this and subsequent infestations in two counties (Imperial and Riverside) in California, were determined by H. H. Keifer, of the State Department of Agriculture at Sacramento, and by H. W. Capps, of the U. S. Bureau of Entomology and Plant Quarantine, Washington, D. C.

The survey for this stem borer extended from southern California into parts of Arizona and Mexico, and observations made of it in these two areas are also reported in this paper. Survey data here presented cover a period of 6 months, from November 1944 through April 1945.

LIFE HISTORY.—The life history of this moth, as related below, is based upon observations of this species as a sugarcane pest in the State of Sinaloa, Mexico, by Van Zwaluwenburg (1926) and Flanders (1930). *Chilo loftini* breeds throughout the year in sugarcane, rice, milo maize, and in many of the larger native grasses. It has approximately a three months' life cycle. Eggs are deposited singly or in clusters, usually between the stalk and the leaf sheath, but they are sometimes placed directly on the leaf. The eggs hatch within a week in Sinaloa, and the larvae, after feeding upon epidermal tissue, ultimately gain entrance to the stalk or stem of the host plant.[2]

In sugarcane the feeding of the larvae is characterized by a transverse tunneling just under the rind of the stalks. The last larval instar is "whitish with four longitudinal broken lines of purple-red" (Flanders 1930), and when mature is almost an inch in length. After the larva has prepared an exit from the tunnel under the rind to the outside, it pupates within a loosely spun cocoon. The adult is an inconspicuous, straw-colored moth, smaller than the adult of *Diatraea lineolata* Walker, the species with which *Chilo* larvae are so often associated in the stalks of sugarcane in western Mexico.

PREVIOUSLY RECORDED INFESTATIONS.

[1] Acknowledgment is made to C. G. Anderson and A. J. Hanson for their invaluable assistance as members of the survey party which was conducted under the leadership of the senior author, to G. J. Bergman for the preparation of the map, and to R. B. Swain for his helpful criticism of the manuscript. The authors are grateful to J. M. Singleton who was in field charge of the Special Survey in the General Vicinity of Ports of Entry, of which this project was a part; his suggestions for assembling the field data made it possible for them to present this paper.

[2] Holloway *et al.* (1928, p. 11), who observed the larvae of *Chilo loftini* on sugarcane in Arizona, reported that this species "has the distinctive habit of feeding on the leaves of cane until rather large, before entering the stalk."

—*Chilo loftini* was reported by Morrill (1925), Van Zwaluwenburg (1926), and Flanders (1930) as a major pest of sugarcane in the State of Sinaloa, Mexico. Van Zwaluwenburg (1926) also reported it from sugarcane in the states of Nayarit and Colima, Mexico, but found this species much more abundant in cane near Los Mochis, Sinaloa, where "85 per cent of all the stalks were infested and about 14 per cent of all the joints." As a result of a survey in 1929 of sugarcane borers near Culiacan, Sinaloa, Flanders (1930) attributed 75 per cent of the infestation in the joints to *Chilo* (remainder to two species of *Diatraea*), and stated that "*Chilo loftini* is the most uniformly distributed and the most numerous of the three species of borers. From the standpoint of fabrication it is the most serious since it opens so many 'portals of entry' for the sucrose-reducing fungus, *Colletotrichum falcatum*," which causes the red rot of canes. Much of the breaking over of cane in the field by strong winds is attributed to the weakened condition of the stalks at the points where the transverse tunnelings of *Chilo* larvae occur.

In previous years *Chilo loftini* had occasionally been reported from the United States infesting sugarcane in Arizona. Records of two infestations in Maricopa County, Arizona, are available. In November 1921, *Chilo* pupae were collected from volunteer sugarcane near Marinette (Glick 1923), and the larvae of this species were reported by Holloway *et al.* (1928) attacking sugarcane and Johnson grass at Phoenix. *C. loftini* was described by H. G. Dyar (1917) from moths reared from cane by U. C. Loftin at Glendale, Ariz. but the exact origin of the infested cane from which these adults were reared is not known. Until the *Chilo* specimens from this survey were forwarded to the U. S. Bureau of Entomology and Plant Quarantine, the Lepidoptera collection of the United States National Museum, Washington, D. C., contained no material of this species from any locality in the United States except a few specimens received several years ago from Arizona.

PLANT QUARANTINE INTERCEPTIONS FROM MEXICO.—On a number of occasions insects identified by specialists as *Chilo loftini* and *Chilo* sp. have been found infesting sugarcane, lemon grass, and corn offered for entry into this country from Mexico. These insects were intercepted in this material by inspectors of the Bureau of Entomology and Plant Quarantine and by State plant quarantine officers of California at ports of entry on the Mexican border. Records in the List of Intercepted Plant Pests (U. S. Bur. Ent. and Plant Quar., S.R.A., 1932–1945) show that, of the three states bordering Mexico in which ports of entry are maintained (California, Arizona, and Texas), in only California and Arizona have insects identified as the above been intercepted. These interception records from Mexico are as follows: *C. loftini* at California twice in sugarcane, at Arizona three times in sugarcane and twice in lemon grass; and

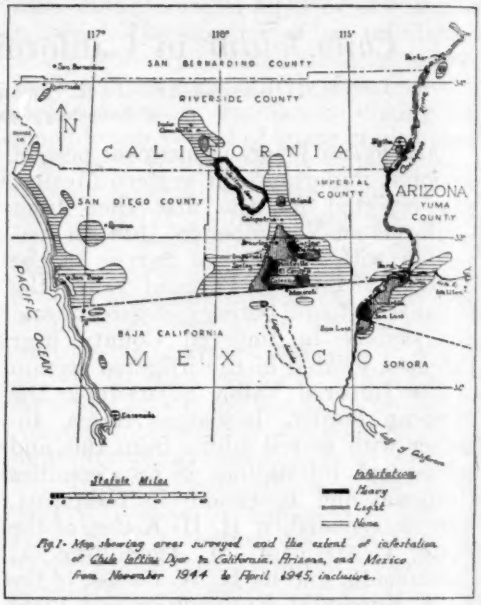

Fig. 1. Distribution of *Chilo loftini*.

Chilo sp. at California once in sugarcane and twice in lemon grass, at Arizona 16 times in sugarcane and twice in corn. Furthermore, *C. loftini* and *Chilo* sp. were intercepted from Mexico at Arizona a number of years prior to their first interception at California.

CALIFORNIA INFESTATION.—The sugarcane in which the larvae of *Chilo loftini* were first found in California on November 28, 1944, was part of a small patch growing in a back yard in Calexico, Imperial County. Several larvae were found boring under leaf sheaths and into stalks in a manner recognized by the senior

author as similar to that of *C. loftini*. The rice field in which larvae of this species were found later in the same day was located near the Mexican border, about 4 miles east of Calexico. The rice was being harvested on the day the infestation was discovered, and about 37 larvae were collected from stubble. Some of the larvae were submitted to the State Department of Agriculture for determination and the remainder kept for rearing.

later, larvae and pupae were collected from the same host near Blythe. No reared material was secured from infestations in this county.

Host plants, together with the localities in the 9 California counties in which these infestations were found, are listed in table 1. The specific localities are more or less grouped, and the general locality is represented by the town around which the majority of collections in that area were

Table 1.—Hosts of *Chilo loftini* and localities in California, Arizona, and Mexico where infestations occurred, as determined by survey from November 1944 through April 1945.

Host	California		Arizona	Mexico
	Imperial Co.	Riverside Co.	Yuma Co.	
Barley	Seeley			
Bristlegrass (*Setaria lutescans*)	Bard			
Bulrush (*Scirpus* sp.)	Brawley, Curlew			
Canna (*Canna* sp.)			Somerton	
Corn	Holtville		Somerton	
Grass (*Echinochloa* sp.)	Curlew, Niland			
Johnson grass (*Sorghum halepense*)	Bard	Coachella, Blythe	Somerton, Parker	
Lemon grass (*Cymbopogon citratus*)	Calexico			Mexicali
Millet (wild)	Bard			
Milo maize	Calexico, El Centro, Holtville, Seeley		San Luis	San Luis
Pampasgrass (*Cortaderia selloana*)		Coachella		San Luis
Rice	Brawley, Calexico, El Centro, Imperial, Sandia, Seeley		Parker	
Sudan grass (*Sorghum vulgarae* var. *sudanense*)	Bard, Calexico		San Luis, Somerton	
Sugarcane	Calexico, Imperial		Yuma	
Unidentified grass	Calexico			

On November 28 and 29, and during December and the first weeks of January, larvae rather than pupae were invariably present in the green stems or old stalks of host plants. By the latter part of February pupae were noticeably abundant. In rice stubble in the vicinity of Calexico the ratios of pupae to larvae collected on February 21 and 22 were 37 to 52 and 35 to 45, respectively. Moths were seen to be emerging from rice stubble in April. Adults of *C. loftini* were reared from immature forms collected from rice, milo maize, sugarcane, lemon grass, and *Echinochloa* sp. in Imperial County.

On March 1, the first infestation of *Chilo loftini* was found in Riverside County, California. The larvae were attacking Johnson grass approximately 7 miles south of Coachella. About 3 weeks

made. In Imperial County immature forms of *Chilo* were found in the stems and stalks of 13 different hosts, including rice, milo maize, sugarcane, sweet corn, and barley. In Riverside County this species was collected from only two hosts, both grasses, in two localities approximately 80 miles apart. (See map: Fig. 1.)

The degree of infestation for a specific area is based on the number of immature forms collected and the subsequent adults reared that were submitted for identification from that area. In addition, the degree of infestation is based on field data included in the daily reports while the survey was in progress. The heaviest general infestation was found in Imperial County in rice east and west of Calexico along the Mexican border, and north in the Imperial Valley to just beyond El

Centro. Heavy but local infestations occurred in rice north of Sandia; in milo maize in the El Centro-Seeley area, and northeast of Holtville; and in the native grass, *Echinochloa* sp., west of Curlew.

Damage by *Chilo loftini* to the 1944 rice and milo maize crops, harvested in the vicinity of Calexico and El Centro in December, was observed by the senior author. In no case were larvae found in numbers great enough to have caused a measurable reduction in the amount of rice harvested, nor was the infestation of one large planting of milo maize in this section sufficient to have a noticeable effect on the yield of the field as a whole.

SURVEY IN ARIZONA.—For 5 months, December 1944 through April 1945, inspections were made in Arizona in the western part of Yuma County, adjacent to California. *Chilo loftini* was reported for the first time in this survey from Arizona on January 19, when both larvae and pupae were found in the stalks of milo maize about a mile west of San Luis. The heaviest infestation observed in Yuma County also occurred in milo maize in this area. Subsequently infestations of five other hosts, including sugarcane and field corn, were found between the Mexican border and the city of Yuma. In March *Chilo* larvae were found in rice growing in the irrigated valley just south of Parker, more than 110 miles north of the border infestation. The host plants and the locality in Yuma County in which each infestation was found are listed in table 1. During this survey adults of *C. loftini* were reared from immature forms collected from milo maize, sugarcane, and Johnson grass in Arizona. (Fig. 1.)

As far as can be determined from available literature, *Chilo loftini* had previously been reported from Arizona only from Maricopa County (Glick 1923; Holloway *et al.* 1928). Presumably the Parker infestation is the most northern record for this species, being about 40 miles north of Marinette, Maricopa County (Glick 1923).

SURVEY IN MEXICO.—As a matter of interest in locating *Chilo* infestations in sections of Mexico more or less contiguous to the United States, arrangements were made in February 1945 by O. A. Pratt, of the Bureau of Entomology and Plant Quarantine, with Josué Zamora y Gonzales, of the Mexican Department of Agriculture, to accompany survey workers into Mexico. Inspections were made in two Mexican States, Baja California and Sonora, which border on California and Arizona, respectively.

On February 8 a survey was made of two areas approximately 10 miles southwest and southeast of Mexicali. Since all sugarcane in this section had previously been cut, milo maize and grasses were examined for borers. A moderate infestation was found in the southwestern area only, where larvae were collected from the stems of lemon grass.

On February 10 inspection in Mexico was carried out around San Luis, where sugarcane, milo maize, canna, and grasses were examined. During 7.5 man-hours spent examining the stems and old stalks of milo maize, one borer was found in a dried stalk; all stems of one clump of pampas grass were found to be infested with *Chilo* larvae.

On February 26 and 27 sugarcane and grasses were suspected in three localities along the western coast of Mexico. No specimens of *Chilo loftini* were found, nor was there any evidence of this species in any of the stalks of plants examined.

During the 4 days of inspection no severe infestation of this species was encountered either in sugarcane, milo maize, grasses, or canna in the areas surveyed in Mexico. A summary of *Chilo* infestations found during this brief survey in Mexico is given in table 1. No adults were reared from the larvae collected near Mexicali (Baja California) or San Luis (Sonora), Mexico.

SUMMARY.—*Chilo loftini* Dyar, a lepidopterous stem borer belonging to the family Crambidae and recognized as a sugarcane pest in Mexico, was reported for the first time from California on November 28, 1944, when it was found in sugarcane and rice stubble in the vicinity of Calexico. It had previously been reported from the United States as attacking random plants of sugarcane in Arizona.

Plant quarantine records show that *Chilo loftini* and *Chilo* sp. have frequently been intercepted as California and Arizona ports of entry on the Mexican border.

According to survey records covering the period November 1944 through April

1945, the heaviest and most extensive infestation of *Chilo loftini* in California occurred within the irrigated section of the lower Imperial Valley, where immature forms of this moth were found in the five crop plants, rice, milo maize, sugarcane, corn, and barley, as well as in several grasses. This borer apparently caused no appreciable reduction in either the rice or the milo maize crop, harvested in December 1944, in the Calexico-El Centro section of the Valley. Light infestations were reported from widely separated localities in Riverside County.

Survey in Arizona and Mexico in areas adjacent to California revealed only spotty infestations of *Chilo loftini*, the most severe occurring in Arizona in milo maize west of San Luis.

Presumably, the following new locality records in Arizona and Mexico have been established by this survey: In Arizona, from Yuma County between the city of Yuma and the Mexican border, and also near Parker, the most northern record for this species; in Mexico, near Mexicali in Baja California and at San Luis in Sonora. —7-20-46.

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Effects of DDT on the Body Louse[1]

GAINES W. EDDY and N. B. CARSON[2], *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The effect of DDT on the body louse, *Pediculus humanus corporis* Deg., has been extensively studied since 1942 at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine. Bushland *et al.* (1945) described experiments which established the military specifications for a DDT louse powder and reported briefly on the rate of insecticidal action of this material. Special studies have been made on speed of knock-down, rate of kill, and ability of the lice to feed and to defecate during exposure to DDT. The observations made during these studies are reported herein.

It is generally believed that the most important method by which typhus fever is transmitted is not directly through the bites of the body louse, but by inoculation with feces or crushed bodies. Feces containing the *Rickettsia* organism may be rubbed or scratched by the host into skin abrasions, and thereby cause an infection. The time required for a treatment to kill lice or to prevent further feeding and defecation is not believed to be an important factor in the breaking up of a typhus epidemic by mass delousing. However, rapidity of action is especially important from the standpoint of psychological reactions to the use of an insecticide, and also in connection with prophylactic treatment of various scientists and other uninfested individuals who may be working in areas in which typhus has reached epidemic proportions.

SPEED OF KNOCK-DOWN AND KILL.—In one test, to obtain information on the speed of knock-down and kill of freshly fed lice, 100 young adults (50 females and 50 males) were placed on cloth pads 1-inch square that were thoroughly dusted with 10 per cent of DDT in pyrophyllite. The lice were kept in open petri dishes at a

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] S/Sgt., U.S.A.A.F., assigned from Army Committee on Aerial Dispersal of Insecticides, Orlando, Fla.

temperature of 30° C. and a relative humidity of approximately 80 per cent. Hourly records were taken over a period of 20 hours.

In another test, to determine whether or not the lack of a blood meal affects the resistance of lice to DDT, two groups of 100 lice each were starved for 14 and 24 hours, respectively, before they were exposed to the DDT.

The results of both these tests are presented in table 1. Lice starved for only 14 hours were less resistant to DDT than hours, the remainder appeared dead when viewed with the unaided eye. After 20 hours all the lice were considered dead.

Lice starved for 24 hours were markedly less resistant than freshly fed lice. After 4 hours 98 per cent of the starved lice were knocked down, as compared with only 62 per cent of the freshly fed lice. After 13 hours all the lice starved for 24 hours were dead, whereas only 50 per cent of the freshly fed lice were dead. Experiments in this laboratory have shown that lice can be starved for 24 hours with

Table 1.—Condition of lice after exposure for different lengths of time to cloth pads dusted with 10 per cent of DDT in pyrophyllite.[1]

Length of Exposure (Hours)	Freshly Fed Lice				Lice Starved for 24 Hours			
	Normal	Affected	Knocked-Down	Dead	Normal	Affected	Knocked-Down	Dead
1	100				96	4		
2	27	72	1		10	71	19	
3	9	89	2			39	61	
4		38	62			2	98	
5		6	94				100	7
6			100				100	17
7			100				100	25
8			100	1			100	60
9			100	14			100	73
10			100	19			100	78
11			100	33			100	98
12			100	47			100	99
13			100	50				100
14			100	60				
15			100	66				
16			100	72				
17			100	78				
18			100	83				
19			100	96				
20				100				

[1] Lice classified as "Normal" could crawl with complete coordination of body movements; "affected" could crawl, but not with complete coordination of body movements; "knocked-down" could not crawl but still alive as evidenced by antennal, gut, or other body movement (usually such lice could not cling to cloth); "dead" showed no visible sign of life as determined by the use of a binocular microscope.

were the freshly fed lice, but the difference was not great.

In the first test, after exposure for 1 hour none of the lice were considered affected. After esposure for 2 hours however, many of the lice had the "DDT tremors" and crawled but little. All the lice might have been classified as affected but, even though tremors were evident, some had the ability to crawl with complete coordination of body movements and were therefore classified as normal. At the end of 4 hours, 62 per cent of the lice were considered knocked down and after 5 hours 94 per cent. Although only half the lice were dead at the end of 13 negligible mortality, and for 48 hours with less than 50 per cent mortality.

The resistance of lice to an insecticide is affected by several factors. Among these are temperature, humidity, age of lice, time lice have gone without blood, and time and methods under which they have been reared in the laboratory. For instance, head lice taken from natural infestations were found to be far less resistant than the body lice present in our laboratory colony. However, after head lice were reared under laboratory conditions for several generations they then became more resistant than head lice taken from natural infestations.

ABILITY OF LICE TO FEED AFTER EXPOSURE TO CLOTH IMPREGNATED WITH DDT.—Besides the rapidity with which a treatment renders the louse incapable of feeding, there are other equally or more important factors that effect the success of a louse-killing material, such as its long-lasting property. To determine the ability of the lice to feed after exposure to DDT, 220 young adult lice (110 males and 110 females), which had been starved for 6 hours, were placed on white broadcloth freshly impregnated with 2 per cent of DDT. These lice were exposed for periods ranging from 15 minutes to 6 hours. The data on the sexes were actually tabulated separately, but since no significant differences were noted between the sexes the figures were combined.

After exposure for 15 minutes, 20 specimens were selected at random and given an opportunity to feed; all 20 lice engorged. After exposure for 1 hour they still appeared to have no difficulty in taking blood. All the lice engorged after they had been exposed for 2 hours, but some of them required a longer time to feed than did those which fed after exposure for 1 hour. Almost 50 per cent of the lice fed after 3 hours and 20 per cent fed after 4 hours. However, only 1 out of 40 lice fed after being exposed for 5 hours and none fed after 6 hours. About half the lice that did not engorge after the 3- and 4-hour exposure periods pierced the skin in an effort to take blood. The bites of the one louse which fed after 5 hours were felt "sharply" several times before it was able to draw blood. When the effects of the DDT had reached a certain stage, the tremors became so severe that the louse simply could not "sit still" long enough to take a blood meal.

None of the lice were knocked down after 2 hours' exposure, but the per cent knocked down after 3, 4, 5, and 6 hours was 2.0, 57.5, 62.5, and 100 per cent respectively. These results are similar to those obtained with the 10 per cent powder (Table 1), although comparative tests were not made.

DEFECATION OF LICE CONFINED ON CLOTH IMPREGNATED WITH DDT.—To obtain information on the rate at which lice defecate, about 1 yard of white broadcloth was impregnated with 2 per cent of DDT. A total of 60 lice—20 males, 20 females, and 20 second-stage nymphs—were allowed to feed on the arms of the authors. While the lice were feeding, the arm was kept under a binocular microscope so that close observations could be made. Some of the lice defecated continuously and in large amounts throughout their feeding, while other defecated only intermittently and in small amounts. However, fecal material was voided at least once by all the lice under observation. No attempt was made to determine the amount or number of defecations while the insects were feeding.

After the lice fed they were divided into two lots, each lot containing 10 males, 10 females, and 10 nymphs. The lice in one lot were confined individually under petri dishes on small pieces of treated cloth, and the lice in the other lot were confined on untreated cloth. Once an hour, after each examination, the pieces of cloth were either turned over or were discarded.

Since it was found too difficult to determine the amount of material voided by the louse, only the number of defecations were counted. Portions of the excrement hardened into fecal specks similar to those voided by the housefly, whereas other portions hardened to form lumps. Each speck or lump was recorded as a defecation. The results obtained in these studies are shown on table 2.

After 1, 2, and 3 hours the total defecation of the lice exposed to the treated cloths was about twice that of the unexposed lice. The defecations made by the insects on the treated cloths decreased rather sharply after the fourth hour and none were noted after the ninth hour, whereas defecations made by the controls remained about the same. The 29 defecations of males shown for the 9–24 hour exposure period indicate a marked decrease in the number of defecations. It is known from past observations that a small amount of fecal material is voided until the starved louse is about to die.

The number of defecations recorded for the females was greater than for the males and nymphs, and since this was true for both the exposed and unexposed females, the amount of blood taken was believed responsible.

KNOCK-DOWN OF LICE EXPOSED TO PYRETHRUM.—For purposes of comparison, records on the effect on lice of pyrethrum, which is one of the most rapidly acting insecticides, are noted here. Ac-

cording to Bushland *et al.* (1944), the time required for the MYL formula, which contains pyrethrum as the primary toxicant, to effect complete knock-down and to render lice incapable of taking a blood meal is much shorter than that required by DDT. Lice were completely immobilized when exposed to MYL powder for 15 minutes, and hungry lice were unable to feed after 10 minutes' exposure. With freshly fed lice, about 50 per cent were killed in 6 hours and 100 per cent after 10 hours' exposure.

Table 2.—Defecation of 30 lice (10 of each stage) exposed to DDT and of the same number of unexposed lice.

Exposure Period (Hours)	Number of Defecations					
	Lice exposed to DDT			Unexposed lice		
	Males	Females	Nymphs	Males	Females	Nymphs
1	19	22	18	12	10	11
2	19	42	19	15	16	12
3	26	34	12	12	17	10
4	16	19	11	14	16	9
5	6	16	2	11	26	9
6	0	2	2	11	12	10
7	1	3	0	14	20	9
8+9	0	3	0	16	37	17
10	0	0	0	—	—	—
9–24	—	—	—	29	—	—

Almost 50 per cent of the lice exposed to cloth impregnated with 2 per cent of DDT continued to feed for 3 hours but were knocked down in 6 hours.

Defecation of lice was stimulated during the first 4 hours' exposure to DDT, but thereafter the rate of defecation dropped sharply and none was recorded after 10 hours, whereas the defecation of unexposed lice remained about the same.

For purposes of comparison, lice exposed to MYL powder, which contains pyrethrum as the primary toxicant, have been reported to be completely immobilized when exposed for 15 minutes, and hungry lice were unable to feed after 10 minutes. With freshly fed lice, about 50 per cent were killed in 6 hours and 100 per cent were found to be dead after 10 hours' exposure.—10-1-46.

SUMMARY.—During the investigations on the effectiveness of DDT against the body louse, *Pediculus humanus corporis* Deg., observations were made on the speed of knock-down, kill and ability of lice to feed and to defecate after exposure to this material.

Lice exposed to a 10 per cent DDT-pyrophyllite powder were completely immobilized in 6 hours. Complete mortality

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Mr. Richard Lewis Post has accepted an appointment as Associate Entomologist in the North Dakota Agricultural Experiment Station at Fargo. Mr. Post was an officer in the Coast Guard for several years during the war and previous to that time had served as Curator of the Entomological Collection at Oregon State College. Earlier, Mr. Post had been employed in the Ward's Natural Science Establishment at Rochester, New York.

Further Tests of the More Promising Materials Against the Body Louse[1]

GAINES W. EDDY and N. B. CARSON,[2] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

About 7500 synthetic organic compounds[3] have been tested at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine to determine their knock-down or paralytic properties against the body louse, *Pediculus humanus corporis* Deg. A few compounds of plant origin were also tested. These tests were made from April 1942 through October 1945. This paper deals only with compounds giving knock-down of lice in 1 hour or less.

Materials giving quick knock-down are desirable for use in the control of insects and prevention of insect-borne diseases. A fast-acting insecticide is also desirable because the average person judges an insecticidal preparation by its knock-down property, and usually fails to recognize the value of a slow-acting but yet highly effective material.

The knock-down and lasting qualities of pyrethrum have been reported by Bushland *et al.* (1944). When tested alone, as little as 0.3 per cent of pyrethrins (prepared from 20 per cent pyrethrum extract) gave knock-down of lice. Although pyrethrum has been in a class by itself for many years, from the standpoint of knock-down, it no doubt will be replaced in time with some synthetic material. The materials listed herein appear to offer some leads for further research.

MATERIALS AND METHODS.—The beaker test method, which was used to determine the initial toxicity and duration of effectiveness of different materials against the body louse, was also used to obtain information relative to knock-down (Bushland *et al.* 1944). Usually the data on speed of knock-down and the toxicity and lasting properties of the material were obtained in the same step.

Circular woolen cloth pads, 1.5 inches in diameter, were dipped into 1 per cent acetone solutions of the test materials. Compounds not soluble in acetone were dissolved in chloroform, benzene, alcohol, water, or some other suitable solvent. In some cases suspensions of the materials were tested. The pads were hung on pins, allowed to dry for 1 to 2 hours, and then placed in 50-ml. beakers together with 10 young adult lice. The lice were kept at a temperature of 86° F. (30° C.) and a relative humidity ranging from 70 to 85 per cent. Examinations were made after 15 and 30 minutes and after 1 hour. Lice that were unable to crawl or to cling to the pads were considered knocked down.

The toxicological tests of many of the materials were made by the United States Food and Drug Administration.

RESULTS.—The compounds have been divided into three groups, according to their effectiveness, and are arranged alphabetically within each group. The materials listed in the first group gave complete (100 per cent) knock-down of lice in 15 minutes, those in the second group in 30 minutes, and those in the third group in 1 hour.

MATERIALS GIVING COMPLETE KNOCK-DOWN IN 15 MINUTES.—Only 30 materials gave complete knock-down of lice in 15 minutes. Although these materials represent the most toxic compounds tested against lice, they appear also to be about the most toxic to man. When considering possible use against lice, several points other than their speed of knock-down must be taken into consideration.

Esters of thiocyanic acids were found to possess good knock-down properties. Some of the materials were effective as ovicides but not as long-lasting louse killing insecticides. Since thiocyanates are known to be fairly toxic to man, they were not considered as possible insecticides for lice.

The amines represent the largest group in the list of materials giving knock-down in 15 minutes. As a chemical group they proved exceptionally good as knock-down agents and fairly good as ovicides, but they were toxic for only a short time. These materials are also generally con-

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] S/Sgt., U.S.A.A.F., assigned from Army Committee on Aerial Dispersal of Insecticides, Orlando, Fla.

[3] Some of these compounds were prepared by the Division of Insecticide Investigations; others were obtained from commercial producers.

sidered toxic to man. Several other compounds in the list fall into the same class with the amines, since they are too toxic to man, stain badly, or have some other objectionable feature which would prevent their being used in most louse-killing preparations.

2-Pivalyl-1,3-indandione was found to be a good ovicide as well as a good louse killer. Toxicologists of the United States Food and Drug Administration found the material safe for use in powder form at a concentration of 1 per cent or less. The material is almost as long-lasting as DDT, and is superior to DDT in speed of kill and in ovicidal effect. However, at concentrations (5 to 10 per cent) required for good results as a louse killer the material is considered too toxic for use on man. The material stains clothing and, being somewhat soluble in water, is removed by laundering.

Benzene hexachloride also proved outstanding in its knock-down and long-lasting qualities, but was found to be a poor ovicide. Clothes impregnated with this material did not withstand washing as did those impregnated with DDT. Perhaps the main objection to this compound is its strong musty odor, although the French (Raucourt 1945) are known to have used it in powder form against body lice. The effectiveness of the material depends largely on the content of its gamma isomer. Some of the other isomers of benzene hexachloride are also toxic, but to a lesser degree.

Indole gave good kill of louse eggs; however, it failed to show lasting value as an insecticide. Toxicologists have found it safe to use in powder form in certain louse-killing preparations.

Some of the anthranilic acid esters proved rather effective as knock-down agents and ovicides, but their effectiveness was of short duration. Other of these esters did possess long-lasting properties, but since they failed to give knock-down of lice they are not included in this paper. The samples of secondary and tertiary butyl esters, which gave knock-down in 15 minutes, may have contained impurities.

MATERIALS GIVING COMPLETE KNOCK-DOWN IN 30 MINUTES.—Twenty-eight compounds gave knock-down in 30 minutes. Many of these materials are also known to be toxic to man. Only three of these compounds showed exceptional ovicidal and long-lasting properties. These, arranged in the order of their toxicity, were omega-piperidinododecylbenzene, o-nitroaniline, and amino tolyl methyl ether. Unfortunately, the first two compounds failed to pass toxicological tests.

MATERIALS GIVING COMPLETE KNOCK-DOWN IN 1 HOUR.—A total of 119 compounds gave knock-down of lice in 1 hour. Approximately half of these failed to pass toxicological tests, and many others either stained badly or had an objectionable odor. Materials used against lice should not only be fast-acting, but should be ovicidal and long-lasting as well. Most of the compounds tested lacked one or more of these properties.

The 10 compounds found to be the most effective and long-lasting were chloromethyl *p*-chlorophenyl sulfone (Lauseto neu); chloromethyl phenyl sulfone; pentachlorophenol; 1,10-dipiperidinodecane; 3-butoxy-2-cyclohexene-1-one; dodecylmorpholine; 4,6-dinitro-*o*-cresol; difluorodiphenyl disulfide; piperonylacetonitrile; and 2-benzylpyridine.

Of the 1-hour group the 8 most toxic ovicides, listed in the order of their apparent effectiveness, were chloromethyl *p*-chlorophenyl sulfone, diflurodiphenyl disulfide, isoquinoline, 4,6-dinitro-*o*-cresol, N-allylaniline, *p*-ethoxypropiophenone, pentachlorophenol, and *p*-ethoxybenzaldehyde.

A few of the materials in this group retained their effectiveness for several days. The 10 compounds that were both ovicidal and long lasting were chloromethyl *p*-chlorophenyl sulfone, difluorodiphenyl disulfide, chloromethyl phenyl sulfone, pentachlorophenol, 4,6-dinitro-*o*-cresol, 1,10-dipiperidinodecane, 3-butoxy-2-cyclohexene-1-one, piperonylacetonitrile 2-benzylpyridine, and dodecylmorpholine.

FACTORS INFLUENCING RESULTS.—It can readily be seen that many of the more effective compounds would prove undesirable as lousicides, owing to their toxicity to man, their tendency to stain, and their objectionable odor. However, in some cases the toxicity may be due to impurities. Impurities can sometimes be removed and odors can often be masked. Temperature and relative humidity are known to have a direct bearing upon the potency of some chemicals. Bertrand

(1919) found that the action of chloropicrin on grain weevils was accelerated by a slight rise in temperature. Moore (1936) obtained a greater kill of California red scale, *Aonidiella aurantii* (Mask.), with hydrocyanic acid gas at lower temperatures than at fairly high temperatures. In experiments with methyl bromide against the confused flour beetle, *Tribolium confusum* Duv., Fisk & Shepard (1938) obtained a greater kill at high than at low humidities, whereas in tests with hydrocyanic acid against the red scale Quayle & Rohrbaugh (1934) obtained less kill at high than at low humidities. A low temperature has been found to increase the speed of knock-down of houseflies, *Musca domestica* L., exposed to DDT (Lindquist *et al.* 1945).

The extent to which humidity influenced the results obtained is not known. Although most of the research done in the past on the effects of temperature and humidity has been conducted with fumigants, it appears that the variations in results depend a great deal upon the species of insect and the insecticide involved. To vary both these factors for each individual compound tested was considered impractical. However, in one experiment comparative tests were made with 29 compounds. One lot was held at a relative humidity of 80 per cent and the other one at approximately 22 per cent for 1 hour. Of the 29 compounds tested, 28 gave identical results at the two humidities. *o*-Methoxypropiophenone showed some variation. It gave 100 per cent knock-down at 80 per cent humidity but only 30 per cent knock-down at 22 per cent.

A number of materials showed fumigating action. No doubt the time allowed for the solvent to evaporate after the cloth was dipped eliminated a number of possible fumigants, especially the highly volatile materials. However, no attempt was made to prevent fumigation, since such information might prove of value later. Some materials, such as benzodioxene and *p*-methoxystyrene, appeared to volatilize, or perhaps decompose, so rapidly that it was necessary to place the lice on the cloth soon after it was dipped. In this way it was possible to determine the knock-down properties of materials which otherwise might have been missed entirely. With a few materials the lice were completely immobilized in 1 hour but were normal at the end of 24 hours.

MATERIALS GIVING COMPLETE KNOCK-DOWN OF LICE IN 15 MINUTES

Anthranilic acid, *sec*-butyl ester
Anthranilic acid, *tert*-butyl ester
Anthranilic acid, methyl ester
Benzene hexachloride, crude
Benzodioxene
Benzylmorpholine
Bis(2-ethoxy-2-butyl-*n*-hexyl)amine
Bis(2-ethoxyamyl)amine
Bis(2-ethoxy-3-methylamyl)amine
2-Chloro-6-nitrotoluene
2,5-Dichloroaniline
5,8-Dimethyl-1-tetralone
Dinitro-*o*-*sec*-butylphenol
N-Dodecylpiperidine
Indole
2-Isovaleryl-1,3-indandione (Valone)
p-Methoxystyrene
N,N-Pentamethyleneglycine, cyclohexyl ester
N-(2-Phenylethyl)piperidine
2-(N-Piperidino)isobutylamine
2-Pivalyl-1,3-indandione (*tert*-butyl Valone)
Propylenediamine
Pyrethrins
Thiocyanic acid, *p*-bromophenyl ester
Thiocyanic acid, 2-(2-butoxy ethoxy)-ethyl ester (80%)
Thiocyanic acid, *p*-iodophenyl ester
Thiocyanic acid, *n*-octyl ester
Tri-*n*-amylamine
Tris (ethylaminomethyl)phenol
alpha, beta, beta-Trimethylglycidic acid, amyl ester

MATERIALS GIVING COMPLETE KNOCK-DOWN OF LICE IN 30 MINUTES

Acetomesitylene
omega-Allylacetophenone
2-Amino-1-phenylethyl ethyl ether
Aminotolylmethyl ether
Anisic acid, methyl ester
Anthranilic acid, ethyl ester
Anthranilic acid, isobutyl ester
4-Bromoacetophenone
4-Chlorobutyrophenone
4-Chloro-2-nitrotoluene
2-Chloroquinoline
Coconut oil fatty acids, beta-thiocyano-ethyl ester (Lethane 60)
Crotonic acid, benzyl ester
(1-Cyclohexenyl)allylacetonitrile
2-(1'-Cyclopentenyl)cyclopentanone
alpha-Decalone
alpha,beta-Dibromo-beta-nitroethylbenzene
Ethyl 2,4,6-trimethylbenzyl ether
Mesitaldehyde
4-Methoxypropiophenone
N-Methylanthranilic acid, methyl ester
alpha-Methyl indole (crude)
3-Methyl-1-phenyl-2-butanol
o-Nitroaniline
2-Octoxyethylmethyl ketone
omega-Piperidinododecylbenzene
1,2,3,4-Tetrachlorobutane
Tributenylamine

MATERIALS GIVING COMPLETE KNOCK-DOWN OF LICE IN 1 HOUR

Acetic acid, 2-benzoyl-2-methyl-1,3-propanediol diester
Acrylic acid, 2-dibutylaminoethyl ester
Alkylbenzyl ethyl ethers
N-Allylaniline
(2-Allylcyclohexylidene)acetonitrile
Allyl *p*-methoxybenzyl ether
p-Allyloxyphenyl bromide
2-Amoxycyclohexanol
N-(*n*-Amyl)succinimide
Anethole
Anisaldehyde
Anisonitrile
Anthranilic acid, *n*-propyl ester
Anthranilic acid, isopropyl ester
Benzophenone
2-Benzoyl-2-methyl-1,3-propanediol crotonaldehyde acetal
2-Benzylpyridine
N-Benzylpyrrole
Bicyclo-(2,2,1)-heptene-2,3,-dicarboxylic acid, diethyl ester
Bicyclo-(2,2,1)-heptene-2,3-dicarboxylic acid, methyl ethyl ester
Biphenyl
Bis(2-thiocyanoethyl)ether
p-Bromobenzonitrile
4-Bromo-o-toluidine
p-Butoxybenzaldehyde
3-Butoxy-2-cyclohexene-1-one
N-Butyl-1,2,3,6-tetrahydrophthalimide
Butyric acid, 2-benzoyl-2-methyl-1,3-propanediol diester
Butyric acid, 1-phenylethyl ester
Carbonic acid, benzyl ethyl ester
Carbonic acid, ethyl *p*-chlorophenyl ester
Carbonic acid, *p*-tolyl ethyl ester
2-Chloroallyl 2-(toloxy)ethyl ether
p-Chlorobenzoic acid, ethyl ester
p-Chlorobenzonitrile
p-Chlorobenzyl cyanide
Chlorocarvacrol
2-(2-Chloro-4-ethylphenoxy)ethanol
p-Chloro-alpha-methoxystyrene
Chloromethyl *p*-chlorophenyl sulfone (Lauseto neu)
Chloromethylphenyl sulfone
3-*p*-Chlorophenoxy-1,2-propylene-oxide
1-(*p*-Chlorophenyl)-2-butanol
1-(*p*-Chlorophenyl)-3-ethyl-2-pentanol
Chlorothymol
4-Chloro-3,5-xylene
alpha - Cyano - beta-ethylidene-alpha-propylvaleric acid, ethyl ester
4-Cyclohexylcyclohexanone
2-Cyclohexylidenecyclohexanone
Cyclopropane-1-acetyl-1-carboxylic acid, butyl ester
Decahydro-1-naphthol
trans-beta-Decalone
N,N-Diamylacetamide
N,N-Diisoamylacetamide
Di-*n*-amyl ketone
o-Dibromobenzene
Difluorodiphenyl disulfide
N,N-Dimethylanthranilic acid, methyl ester
2,3-Dimethyl-2-octenenitrile
4,6-Dinitro-*o*-cresol
1,4-Dioxaspiro-(4,4)-nonane-6-carboxylic acid, ethyl ester
1,10-Dipiperidinodecane
Dodecylmorpholine
Ephedrine
o-Ethoxybenzaldehyde
p-Ethoxybenzaldehyde
p-Ethoxypropiophenone
2-Ethylchromanone
2-Ethylchromone
Ethylidenemalonic acid, diethyl ester
N-Ethyl-N-phenylurethane
Furfurylidene acetone
N-(2-Furfurylidene)-*o*-toluidine
Furylacrylic acid, ethyl ester
Hexachloro-2,5-cyclohexadiene-1-one ("Hexachlorophenol")
4-(*o*-Hydroxybenzyl)morpholine
o-Hydroxyvalerophenone
o-Iodonitrobenzene
p-Iodophenetole
Isobutyl phenyl carbinol
p-Isopropoxyacetophenone
p-Isopropoxybenzaldehyde
N-Isopropylacetanilide
alpha-Isopropylidenesuccinic acid, diethyl ester
Iso-quinoline
Menthol
2-Methallyl-4-methylcyclohexanol
p-Methoxyacetophenone
o-Methoxypropiophenone
1-Methylbenzothiazole
alpha-Methylepoxy-(4-methylcyclohexylidene) acetic acid, methyl ester
2-Methyl-1-indanone
Methylphenylnitrosoamine
N-Methyl-N-phenylurethane
3-Methyl-2-propyl-2-hexenenitrile
2-Methyl-3-propyl-2-hexenenitrile
7-Methylquinoline
Nicotyrine
p-Nitroanisole
m-Nitrophenyliodochloride
Octylamine
Oil of anise seed
Oil of parsley seed
PD-544-C, broad fraction (mixture of methyl and polymethyl naphthalenes)
Pentachlorophenol
Piperonylacetonitrile
Propionic acid, 2,4-dinitrophenyl ester
Propiophenone oxime
p-*n*-Propoxybenzaldehyde
Salicylic acid, allyl ester
Salicylic acid, isopropyl ester
Sebaconitrile
2,3,4,6-Tetrachlorophenol
1,2,3,4-Tetrahydroquinoline
Thiocyanic acid, n-tetradecyl ester
3-*o*-Toloxy-1,2-propylene oxide
2-*o*-Tolylethanol
Velsicol AR-50 (chiefly mono- and dimethylnaphthalenes)
Vinyl mesityl ketone

SUMMARY.—Approximately 7500 compounds were tested from April 1942 through October 1945 to determine their knock-down effect on the body louse. *Pediculus humanus corporis* Deg. The materials were tested at a concentration of 1 per cent in acetone or some other suitable solvent. Circular woolen cloth pads were dipped into these solutions,

allowed to dry for 1 to 2 hours, and then placed in 50-ml. beakers together with 10 young adult lice. During the tests the lice were held at a temperature of 86° F. (30° C.) and a relative humidity of approximately 75 per cent. Examinations were made after 15, 30 and 60 minutes.

Of the compounds tested 29 gave knockdown of lice in 15 minutes, 29 in 30 minutes, 120 in 1 hour. The lasting properties, the ovicidal properties, and certain other characteristics of some of the better materials are also discussed.—7-16-46.

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Flea Repellents for Use on Clothing[1]

J. P. LINDUSKA, J. H. COCHRAN, and F. A. MORTON, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In studies made at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine in 1942 certain materials, such as dimethyl phthalate, *Rutgers 612* (2-ethyl-1,3-hexanediol), and *Indalone* (*n*-butyl mesityl oxide oxalate), which were issued to military personnel as mosquito repellents were also found to protect against biting by fleas when applied to the skin (Lindquist *et al.* 1944). In 1944 particular attention was given to the testing of chemicals that would repel fleas when impregnated in cloth. The results of preliminary tests of 112 compounds or mixtures, together with practical tests of several of these materials impregnated in uniforms, are reported in this paper.

The fleas used, *Ctenocephalides canis* (Curt.) and *C. felis* (Bouchè), were reared in the laboratory (Linduska *et al.* 1946).

PRELIMINARY TESTS.—Acetone solutions of selected repellent materials or mixtures of these materials were impregnated in khaki cotton-twill strips, 3 by 18 inches, at the rate of 8 grams of repellent per square foot. The strips were dried and then waved around, one at a time, in a washtub containing several thousand adult fleas. One end of the strip was held about an inch from the bottom of the tub, and in a few seconds 50 or more fleas were present on the strip. The cloth was then raised over the tub, out of jumping range of the fleas, and held in that position for 30 seconds. The fleas remaining on the cloth were then counted. Untreated strips were exposed concurrently as checks. Exposures and counts for each material were made in triplicate. The repellency was evaluated as per cent reduction in the number of fleas on the treated cloth below the number on the untreated cloth.

In similar tests against mosquitoes it was found that the treated fabric must contact the skin before valid measurements of repellency could be obtained. This method of screening materials as flea repellents was checked by a simulated practical test in which chemically treated fabrics were worn in contact with the

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

skin. Women's cotton hose were impregnated with some of the materials used in the previous tests at the rate of 8 grams of repellent per square foot. The test subject wearing the hose stood in a tub containing several thousand adult fleas. The number crawling above the knee line in a 4-minute exposure was compared with the number reaching the same place when untreated hose were being worn. The relative repellency rating of materials tested by the two procedures was very similar, and it appeared that a reliable rating could be obtained without having the treated fabrics contact the body.

The results obtained with the treated fabric method are listed below, in order of effectiveness:

Chemicals Giving 91 to 100 Per Cent Reduction

alpha-Decalol	100
2,3,4,6-Tetrachlorophenol	100
2,3,4,6-Tetrachlorophenol 50%+*p*-phenylphenol 50%	100
2-Hydroxy-3-methoxybenzaldehyde	100
alpha-Naphthol	[2]100
2,4,6-Trichlorophenol	100
2,3-Dimethoxybenzaldehyde	[2] 98
alpha-Naphthylamine	98
2,3,4,6-Tetrachlorophenol 50%+2-chloro-4-phenyl phenol 50%	98
p-iso-Prophylphenylethyl alcohol	[2] 98
p-*n*-Propoxybenzaldehyde	[2] 98
N-*sec*-Butyl phthalimide	97
5-Hydroxy-1,3-dimethylbenzene	97
2,4,5-Trichlorophenol	97
Hexachlorophenol	97
1-(*p*-Methoxyphenyl)-2-methyl-1,3-propandiol methylene ether	97
1,2,3,4-Tetrahydro-2-naphthol	94
Benzoic acid, benzyl ester	94
p-Methoxyacetophenone	94
p-*tert*-Butylphenol	94
Pentachlorophenol	94
Alkyl benzyl ethers of ethylene glycol	93
4-Methoxy 3-methyl-acetophenone	92
Chlorothymol	92
Pyrocide 160 (pyrethrins 20%)	92
2,6-Dichloro-4-*tert*-amylphenol	91

Chemicals Giving 76 to 90 Per Cent Reduction

2-Hydroxy-3-methoxybenzaldehyde	90
Acetic acid, 2-phenoxyethyl ester	90
Monocyclohexyl ether of dipropylene glycol	90
o-Hydroxydiphenyl	89
Anisic acid, methyl ester	89
Pyrocide 160 50%+piperonyl cyclohexenone 50%	89
Dinitro-*o*-*sec*-butylphenol	89
p-Methoxybenzyl alcohol	89
beta-Hydroxyethyldodecylamine	88
Monocyclohexyl ether of diethylene glycol	88
Mandelic acid, ethyl ester	88
N-Butyl-1,2,3,6-tetrahydrophthalimide	88
2-Phenylcyclohexanol	86
Anthranilic acid, *n*-propyl ester	86
Hexahydrophthalic acid, diethyl ester	85
Mandelic acid, isobutyl ester	84
N-Propylphthalimide	84
1-(*p*-Chlorophenyl)-3-methyl-2-butanol	84
Phenylcyclohexanone	84
Pyrocide 160 50%+N-isobutylundecylenamide 50%	84
beta-Naphthol	83
p-Nitroanisole	81
N,N-Dipropylsuccinamic acid, ethyl ester	81
Propionic acid, pentamethylene diester	80
2(2-Chlorophenoxy)ethanol	78
o-Nitroaniline	77

Chemicals Giving Less Than 76 Per Cent Reduction

p-Anisidine	75
Piperonal (heliotropine)	74
3-Bromo-4-hydroxydiphenyl	74
2,6-Dimethylnaphthalene (Velsicol E-prime)	73
cis-Bicyclo(2,2,1-5-heptene-2,3-dicarboxylic acid, dimethyl	73
Benzene hexchloride (hexachlorocyclohexane)	73
2,4-Dinitro-*o*-cresol	72
4,4-Dimethyl-2-phenyltetrahydrooxazole	71
N-*n*-Propylacetanilide (N-*n*-Propyl-N-phenylacetamide)	70
2-Nitro-2-methyl-1,3-propanediol butyraldehyde acetal	69
2-Ethylbutyric acid, 1,4-butanediol diester	69
2,4-Dinitrobromobenzene	69
3-Ethoxy-4-hydroxybenzaldehyde	69
N-beta-Chlorethyl trichloroacetamide	67
1-Benzyl-cyclohexanol-1	67
3,5-Dinitro-*o*-cresol	66
3-Methyl-4'-bromodiphenyl	65
Piperonyl alcohol	65
2,3-Dichlorobutyramide	65
Phthalic acid, dimethyl ester, 60%, *Rutgers 6–12* 20%, and *Indalone* 20% (6-2-2 mixture)	65
Bicyclo-(2,2,1)heptene-2,3-dicarboxylic acid, diethyl ester	65
2(2,4-Dichlorophenoxy)ethanol	64
Mesityl oxide oxalic acid, *n*-butyl ester (*Indalone*)	62
Cyclohexylcyanoacetic acid, ethyl ester	60
2,4-Dinitrophenol	59
Lauric acid, ammonium salt (anhyd.)	59
Tonkene P (mixture of coumarin and phthalide)	58
Epoxymethylphenyl acrylic acid, ethyl ester	57
dl-Malic acid, *n*-butyl ester	56
2-(*o*-Hydroxyphenyl)-1,3-dioxolane	56
5,8-Dimethyl-1-tetralone	55
N-Methylacetanilide	55
Phthalic acid, dimethyl ester	55
Ethyl vanillin	53
2,2,3-Trichloropropionamide	51
Coumarin	50
Valone	49
2,4,7,9-Tetramethyl-5-decynediol-4,7	48
DDT (1-Trichloro-2,2-bis(*p*-chlorophenyl)-ethane)	46
2,5,7-Trimethyl-3-octynediol-2,5	46
Caproic acid, 1,2-propanediol diester (85%)	46
Acetic acid, 2,2'-thiodiethanol diester	45
Lauric acid, propylene glycol monoester	42
Decahydro-2-naphthol	42
Vanillin	39
2-Ethyl-2-butyl-1,3-propanediol	36

[2] In preliminary tests made by the U. S. Food and Drug Administration, these materials were found safe (from an irritation standpoint only) for further tests.

m-Dinitrobenzene	35
n-Decaldehyde (*Aldehyde C*-10)	32
N-(mixed monoamyl) imide of 3,6-endomethylene-4-cyclohexene-1,2-dicarboxylic acid	30
Lethane 384 special (an aliphatic thiocyanate)	30
2,4-Dinitroanisole	29
Thanite (mixture of fenchyl and borneol thiocyanoacetates	24
Catechol)	23
Dibutyl isobutylcarbinol	17
Naphthenic acid, glyceryl ester	17
n-Butyl sulfone	17
Phenylethyl malonic acid, diethyl ester	17
2-ethylhexanediol-1,3	12
Ethyl-beta-methyl cyanosuccinate	11
Phenoxyacetic acid	0

Only 6 of 112 compounds gave 100 per cent control, according to the arbitrary standards established for screening tests, but 20 others gave 91 to 98 per cent. The combination of dimethyl phthalate, *Rutgers 612*, and *Indalone* (known as the 6-2-2 mixture) was less than 75 per cent effective. As skin repellents these materials were previously found to prevent insect bites when used individually at full strength (Travis *et al.* 1936). None of the compounds prevented fleas from jumping onto the test strips, but the more effective ones caused all fleas to leave the strips within 10 seconds.

The possible toxicity and irritation to man of many of the compounds tested is not known, and some may be unsuitable for use.

PRACTICAL TESTS.—Tests were also made to determine the protection provided against fleas by clothing impregnated with repellents. Military fatigue pants were impregnated with several of the better mosquito repellents, together with a few materials that were found to be the most effective against fleas in the screening tests. Trouser legs and socks were dipped into a repellent that was sufficiently diluted with acetone to give an impregnation of 5 grams of chemical per square foot. To facilitate observing the number of fleas crawling beneath clothing, only the legs of the trousers, which had been cut off, were treated. With this arrangement it was convenient to look into the tops of the cut-off trouser leg at intervals and observe the number of fleas on the legs and the distance they had crawled. Subjects wearing clothing treated with different materials on each leg were exposed by standing for 15 minutes in a tub containing several thousand fleas. On subjects wearing untreated clothing several hundred fleas reached the belt line in 2 to 3 minutes.

The protection obtained with the compounds tested is given below:

2-Pheynlcyclohexanol
Good. Few on socks. None crawled up trouser legs.

p-iso-Prophylphenylethyl alcohol
Good. Few on socks. None crawled up trouser legs.

1,2,3,4-Tetrahydro-2-naphthol
Good. Few on socks. None crawled above sock line, none on trouser legs.

Benzyl benzoate
Fair–good. Comparatively few on socks and trouser leg. No bites.

Indalone
Fair. Many on socks: none crawled above knee either inside or outside trouser leg.

Dimethyl phthalate 60%, Rutgers 6–12 20%, and Indalone 20% (6-2-2 mixture)
Fair–poor. Many crawled above sock line. One bite above sock.

Dimethyl phthalate
Fair-poor. Many on socks. Several bites through socks. One bite at waist line.

Rutgers 6–12
Ineffective. Several hundred above sock line in 3-minute period.

SUMMARY.—Tests for repellency to fleas were made on 112 compounds or mixtures by impregnating cloth strips and exposing them to heavy flea populations. At least 26 materials were strongly repellent to fleas and gave over 90 per cent reduction. Several materials impregnated in clothing were found to have the same order of repellency previously established in screening tests. Benzyl benzoate and 2-phenylcyclohexanol were found to be considerably more effective as clothing treatments against fleas than the insect repellents (dimethyl phthalate, *Indalone*, and *Rutgers 6-12*) issued for use by the armed forces. *p*-iso-Prophylphenylethyl alcohol and 1,2,3,4-tetrahydro-2-naphthol also gave complete protection, but their possible toxic or irritating properties have not yet been established.

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An Oil-DDT Vapor Spray to Control Grape Leafhopper

PAUL R. JONES, L. C. GLOVER and ROY HANSBERRY[1]

When DDT was made available for widespread experimental work in 1944, the Shell Oil Company, Incorporated, received allocations which permitted moderately extensive field tests in addition to laboratory work. With no information as to specificity, it was decided to concentrate the work on control of grape leafhopper[2] for the following reasons:

1. Applications were made before blossoming, eliminating residue problems.
2. Large tonnages of raisins needed by the Armed Forces were endangered by attacks from this pest.
3. Pyrethrum extract, previously used in controlling the pest, was not available.

The use of atomized oils containing pyrethrum extract for the control of grape leafhopper in California and Arizona is a well established practice. Their effectiveness rests largely on the development of a special atomizer for their application (Fig. 1). With this Johnson vapor machine approximately 4 gallons per acre are applied at a cost of $1.30 to $1.75 per acre for materials and $1.00 to $1.50 for use of machine and crew. Most grapes are sprayed by contract operators rather than with grower-operated machines.

FIELD EXPERIMENTS IN 1944.—In 1944 tests, which were located at the Sierra Vista Ranch of the Di Giorgio Fruit Corporation near Delano, California, covered 100 acres and included several varieties of grapes. Concentrations of DDT ranging from 0.05 to 2.4 per cent by weight were used in a vapor spray oil base blended from highly refined kerosene and a light grade spray oil. Numerous standard or check plots were sprayed with the same base containing 3.0 per cent by volume of 20 to 1 pyrethrum extract[3] (0.046 per cent pyrethrins by weight in finished spray).

The Johnson vapor sprayer was used in the tests, applying the test materials at the rate of 4 gallons per acre.

Although there was no immediate knockdown of the leafhoppers, such as occurs with pyrethrum, the three highest concentrations (0.6, 1.2 and 2.4 per cent) gave complete control of the leafhoppers. Observations made later in the season showed that these vines remained substantially free from leafhopper infestation, even on new foliage grown subsequent to application.

FIG. 1.—Special atomizer designed to produce vapor spray.

Applications were made in the spring when new growth was from 8 to 24 inches in length. At this time all leafhoppers present were overwintering adults. In cases where eggs had been laid before application, nymphs hatching from eggs were apparently killed upon hatching since no nymph population developed on the DDT sprayed plots, although plentiful on pyrethrum plots. This observation was confirmed by the 1945 work.

FIELD EXPERIMENTS IN 1945.—The 1945 experiments were designed to cover a wide range of conditions. Following the limited experimental work with DDT in 1944 a field survey was made of all the vineyard areas where grape leafhoppers existed in injurious numbers. From this

[1] Paul R. Jones was Senior Technologist, Technical Products Department, Shell Oil Company Incorporated, San Francisco (now retired). L. C. Glover and Roy Hansberry are Senior Entomologist and Director, respectively, Shell Agricultural Laboratory, Modesto, California.

[2] In the San Joaquin Valley where most of the work was done *Erythroneura elegantula* (Osborn) was most prevalent. In the Salt River Valley in Arizona both *Erythroneura variabilis* (Beamer) and *Diakroneura cockerelli* (Gillette) were present.

[3] Sold by Shell Oil Company, Incorporated, under the trade mark *Vapona No. 1.*

the 1945 experiments were located in the Salt River Valley in Arizona, the Coachella Valley in Southern California and in the San Joaquin Valley of California. These experiments included about 15,000 acres of vineyard with 25 different varieties of raisin, table, and wine grapes.

The experiment was designed to determine, under practical field conditions, the initial kill and the residual effect on both adults and nymphs of the grape leafhopper, and to obtain further knowledge on any factors arising from the extensive use of a new insecticide.

The materials used in 1945 contained 0.6, 1.2, and 2.4 per cent DDT by weight. The DDT is in solution in a special petroleum oil base consisting of approximately nine parts of a highly refined kerosene and one part of a light spray oil. This blend of oils has a minimum U. R. of 92.0 per cent.

Pyrethrum was used as a check material. This was the same oil blend as was used with DDT. It contained 3.0 per cent pyrethrum by volume.

Application of the spray was made with several types of equipment. A Johnson Vapor spray machine or a modification of this machine was used in most vineyards. These machines usually carry 50 gallons of spray. This is pumped to two semi-fishtails with openings 16×1 inch and delivered into the center of the air stream from a tube, with holes in each side, running the length of the fishtail. Air in one type machine is supplied by one 5 inch outlet centrifugal blower mounted horizontally, and more commonly, from two 4 inch outlet centrifugal blowers mounted vertically. The fishtails are set low and directed upward in order to hit the lower surfaces of the leaves. Motive power for the fan is furnished by a separate power unit.

Four additional types of machines were used in Arizona and in the Coachella Valley. These included a standard *Hardie Estate Sprayer* with a 2-nozzle gun operated manually, and a *Vapo-duster*, normally used for applying tartar emetic for thrips control in Arizona citrus orchards. This sprayer had all of the nozzles blocked off except the two lowest and gave good coverage although the droplet size was somewhat larger than desirable. In the Coachella Valley a *Bean Duster* converted for vapor application was used but gave only fair coverage with large droplets, apparently because of an insufficient air blast. One of the early models of the *Todd Insecticidal Fog Applicators* was used in Arizona and gave good initial kills although the residual toxicity apparently did not last as well as with the other types of sprayers. With this varied equipment surprisingly good kill was obtained even where coverage was poor or where spraying was done under poor conditions, particularly in windy weather.

All materials used in the San Joaquin Valley were applied with *Johnson Vapor Spray Machines* or some modification of this machine. Dosage varied from about 3 to 5 gallons of spray per acre. The majority of the acreage treated received 4 to 4.5 gallons per acre. Pyrethrum was used as a check material.

Pretreatment counts were made not longer than 48 hours before the spray was applied. In many blocks the pretreatment counts were made a few hours before treatment. Post-treatment counts were made during a period of 48 to 120 hours. Other observations of adult leafhoppers and counts of nymphs were made at 30, 60, and 90-day intervals following treatment.

Counts were made by hand spraying individual vines with a spray consisting of 5 per cent of a 20–1 pyrethrum concentrate in a kerosene-type carrier. As leafhoppers fell they were collected on large black cloths spread under the vines and counted.

Much of the spraying was done during daylight but a large amount of night spraying was done on the Di Giorgio farms in Arvin. Conditions were nearly perfect during the late evening. The oil vapor fog hung over the vineyards sometimes for 20 to 25 minutes. In the larger vineyards the *Johnson Vapor Spray Machines* were operated in pairs, threes, or fours. This method of application gave excellent coverage of the foliage. All treatments except with the *Todd Insecticidal Fog Applicator* were made by operating a machine on every other center. One 25 acre block was treated in a wind ranging from 15 to 20 miles per hour with excellent results. In this case the machine was operated on every center.

DDT RESIDUE ON GRAPES TREATED AFTER BLOSSOMING.—Nearly all of the treatments on grapevines were made before bloom. A few were treated during bloom. It was thought desirable to treat a few vines after blossoming in order to determine the amount of DDT residue remaining on the fruit at harvest time. DDT *Vapona* at 0.6, 1.2, and 2.4 per cent by weight was applied to three varieties of grapes, Thompson Seedless, White Malaga, and Carignane, on May 29. Five gallons of *Vapona* per acre were applied when the grapes were in the buckshot stage of development. Grapes were harvested at different times from the treated vines and from untreated vines. Grapes harvested at maturity were analyzed for DDT by W. M. Hoskins, Department of Entomology, University of California at Berkeley. Results are as follows:

From 5.0 to 2.6 parts per million for 0.6 per cent DDT *Vapona*

From 1.6 to 3.2 parts per million for 1.2 per cent DDT *Vapona*

From 3.5 to 5.8 parts per million for 2.4 per cent DDT *Vapona*

THE EFFECT OF DDT VAPOR SPRAY ON BENEFICIAL INSECTS.—The lady beetle *Hippodamia convergens* Guerin was numerous in both pyrethrum and DDT sprayed blocks after treatment, indicating no deleterious effect on this insect.

Specimens of the Hymenopterous egg parasite *Anagrus epos* Girault were nu-

Table 1.—Control of Grape Leafhoppers—Sierra Vista Ranch, San Joaquin Valley.

VARIETY	ACRES	MATERIAL	PRE-TREATMENT ADULTS PER VINE	POST-TREATMENT ADULTS PER VINE
Thompson Seedless	60	0.6% DDT *Vapona*	42.0	0.20
Thompson Seedless	120	0.6% DDT *Vapona*	368.0	0.06
Thompson Seedless	100	1.2% DDT *Vapona*	50.0	0.25
Thompson Seedless	80	1.2% DDT *Vapona*	190.0	0.60
Thompson Seedless	40	1.2% DDT *Vapona*	207.0	0.02
Thompson Seedless	20	1.2% DDT *Vapona*	114.0	0.10
Thompson Seedless	80	1.2% DDT *Vapona*	103.0	0.00
Thompson Seedless	60	1.2% DDT *Vapona*	153.0	0.30
Thompson Seedless	20	1.2% DDT *Vapona*	378.0	0.90
Thompson Seedless	80	1.2% DDT *Vapona*	152.0	0.30
Thompson Seedless	80	2.4% DDT *Vapona*	84.0	0.00
Thompson Seedless	20	2.4% DDT *Vapona*	155.0	0.50
Thompson Seedless	20	2.4% DDT *Vapona*	152.0	0.50
Thompson Seedless	60	2.4% DDT *Vapona*	37.0	0.10
Thompson Seedless	80	3.0% Pyrethrum *Vapona*	48.0	8.90
Thompson Seedless	160	3.0% Pyrethrum *Vapona*	209.0	9.00
Thompson Seedless	100	3.0% Pyrethrum *Vapona*	37.0	4.50
Thompson Seedless	160	3.0% Pyrethrum *Vapona*	313.0	72.00
Ribier	20	0.6% DDT *Vapona*	55.0	0.30
Ribier	54	0.6% DDT *Vapona*	98.0	0.50
Ribier	20	1.2% DDT *Vapona*	27.0	0.15
Ribier	20	3.0% Pyrethrum *Vapona*	57.0	2.00
Emperor	20	0.6% DDT *Vapona*	128.0	0.50
Emperor	40	0.6% DDT *Vapona*	28.0	0.40
Emperor	80	1.2% DDT *Vapona*	63.0	0.10
Emperor	80	1.2% DDT *Vapona*	45.0	0.20
Emperor	20	1.2% DDT *Vapona*	18.0	0.20
Red Malaga	33	1.2% DDT *Vapona*	35.0	0.00
Red Malaga	80	1.2% DDT *Vapona*	59.0	0.10
Red Malaga	132	1.2% DDT *Vapona*	157.0	0.40
Muscat	40	1.2% DDT *Vapona*	47.0	0.25
Muscat	40	3.0% Pyrethrum *Vapona*	47.0	12.00
Burger	20	0.6% DDT *Vapona*	33.0	0.07
Black Monukka	100	1.2% DDT *Vapona*	35.0	0.30
Cornichon	60	1.2% DDT *Vapona*	28.0	0.10
Cornichon	80	2.4% DDT *Vapona*	54.0	0.40
White Malaga	60	1.2% DDT *Vapona*	37.0	0.20
Wine Grapes	20	1.2% DDT *Vapona*	308.0	0.00

merous in vineyards sprayed with DDT *Vapona*.

Some blocks of White Malaga, Emperor, and Ribier grapes were infested with mites before treatment. These grapes have a hairy underleaf surface. The mite was determined by Dr. H. H. Keiffer of the California State Department of Agriculture, as *Tetranychus willametti*. There was no apparent difference in the infestation on the pyrethrum and the DDT treated blocks at the end of the season.

RESULTS.—The results of work done on the Di Giorgio Fruit Corporation's Sierra Vista Ranch is typical of all the area in the San Joaquin Valley and is summarized in table 1. This part of the experiment included 2359 acres of vineyard. Other areas in the experiment included the following acreage. Salt River Valley, 129, Coachella Valley, 1209 (summarized in table 2) Northern San Joaquin Valley, 2400, Central San Joaquin Valley, 2159, Delano area exclusive of the Sierra Vista Ranch, 2525, and the Southern San Joaquin Valley, 3956, making a total of 14,737 acres.

Observations made June 5, July 16, August 16, and September 25, 1 to 4 months after treatment, showed that leafhopper populations did not build up appreciably on DDT sprayed plots until after most varieties were harvested. Where large blocks were sprayed the population stayed low through September. On the other hand, blocks sprayed with pyrethrum developed high populations of adults and nymphs a week to a month after treating. On July 16 the pyrethrum blocks at Sierra Vista Ranch were all retreated, and a third treatment was necessary in August to reduce leafhopper populations. In spite of three treatments more leafhoppers were present throughout the season than where a single early application of 0.6 per cent DDT *Vapona* was made.

In the Coachella valley inferior application equipment was used. At the time of treatment the coverage was so poor little control was expected. The results given in table 2 show that even under these conditions adequate to excellent control was obtained, especially with 2.4 per cent DDT *Vapona*. This observation was responsible for the decision to market a *Vapona* containing 2.4 per cent DDT[4] even though the 1.2 per cent product gave good results under average conditions.

Table 2.—Control of grape leafhoppers. Vineyard Area—Coachella Valley—California.

VARIETY	ACRES	MATERIAL	PRE-TREATMENT	POST-TREATMENT AVE. COUNT PER VINE			PER CENT REDUCTION
			Ave. Count per vine	24 hours	7 days	21 days	Adults—21 days
Thompson	5	1.2% DDT *Vapona*	88	2.4	4.0	3.0	97.0
Thompson	20	1.2% DDT *Vapona*	73	3.0	2.0	2.0	97.0
Thompson	200	1.2% DDT *Vapona*	64	3.0	1.6	2.0	97.5
Thompson	200	1.2% DDT *Vapona*	42	4.0	4.0	2.1	95.0
Thompson	140	1.2% DDT *Vapona*	200	2.0	1.0	1.0	99.0
Tnompson	140	2.4% DDT *Vapona*	201	1.0	1.0	2.0	99.0
Thompson	200	2.4% DDT *Vapona*	250	14.0	1.4	3.0	99.0
Thompson	9	2.4% DDT *Vapona*	467	22.0	13.0	27.0	97.0
Thompson	295	2.4% DDT *Vapona*	55	3.0	2.0	0.8	98.5
Thompson	One block	3.0% Pyrethrum *Vapona*	250	107.0	Retreated with DDT *Vapona*	—	—

Observations in the vineyard at the Shell Agricultural Laboratory at Modesto, California. On this limited acreage more frequent counts and observations could be made than on the extensive acreage in other areas. In addition foliage that had received the DDT sprays in May was caged and adult grape leafhoppers placed in the cage for

[4] Now sold by Shell Oil Company, Incorporated, under the trade mark *Vapona No. 1D*.

Table 3.—Residual toxicity of DDT Vapor and emulsion to the grape leafhopper—Modesto, California.

Treatment	Foliage Caged 75 Days After Spray Application				Foliage Caged 82 Days After Spray Application			
	Total in 5 cages	Total after 7 days		Per cent Dead	Total in 5 cages	Total after 7 days		Per cent Dead
		Alive	Dead			Alive	Dead	
	Total in				Total in			
Check (Untreated)	125	118	7	5.6	125	112	13	11.6
2.4% DDT *Vapona*	125	93	32	25.6	125	80	35	28.0
1.2% DDT *Vapona*	125	71	54	43.2	125	67	58	46.4
0.6% DDT *Vapona*	126	110	16	12.6	125	86	39	31.2
Medol Light spray oil+5% DDT[1]	123	3	120	97.5	123	11	112	91.0
Medol Light Medium spray oil+5% DDT[1]	124	0	124	100.00	121	0	121	100.00

[1] The *Medol* oils are standard type emulsive summer oils to which were added 5% by weight of technical DDT. The resulting emulsive DDT-oil was emulsified using 1.5 gallons oil per 100 gallons water and applied with a standard orchard spray gun at the rate of 1.5 to 2 gallons per vine.

7-day intervals. The cages were of the sleeve type and were 10 inches in diameter and 12 inches long, covered with bleached muslin. Cages were placed so five leaves were in each cage. Twenty-five adult leafhoppers were placed in the cage and the outer end tied. Five replicates were used and a second test was set up immediately following the first test. Results are summarized in table 3. Although substantial toxicity is still shown from light vapor DDT sprays 85 days after treatment, the remarkable residual toxicity of the oil emulsion containing DDT is especially noteworthy. However, this application was comparatively slow and drenching sprays were applied to each vine. Since the vapor sprays gave good results, the emulsion spray probably would not be commercially practicable in California.

SUMMARY.—Field tests totalling 100 acres were conducted in one vineyard during the 1944 season. Concentrations ranging from 0.05 to 2.4 per cent by weight of DDT were used. Results indicated a residual effect. Concentrations of 0.6 per cent by weight or higher were necessary for complete kill of adult leafhoppers. Pyrethrum was used as a check material.

In 1945 field tests were conducted in the Coachella and San Joaquin Valleys of California and in the Salt River Valley of Arizona. The greater part of the 1945 work was done using a spray containing 1.2 per cent DDT by weight. Concentrations of 0.6 and 2.4 per cent by weight were also used together with pyrethrum controls.

Applications were made with *Johnson Vapor Sprayers*, singly or in banks of 2, 3, or 4, a *Hardie Estate Sprayer*, a *Bean Vapo-duster*, a modified *Bean* duster, and a *Todd Insecticidal Fog Applicator*. The dosage ranged from about 3 gallons to 5 gallons per acre.

Counts of leafhopper populations were made previous to treatment, immediately following treatment, and at 1, 2, and 3 month intervals after treatment.

Residue tests were conducted on three varieties of grapes. Determinations of DDT spray residue at harvest showed a maximum of 5.8 parts per million of DDT with the highest concentrations used, that is, 2.4 per cent DDT applied at the rate of 5 gallons per acre to grapes in the buckshot stage.

No foliage injury was noted. Lady-bug beetles and the egg parasite *Anagrus epos* Girault were present in normal numbers in the vineyards after application. The Willamette mite did not build up on blocks sprayed with DDT more than on the pyrethrum treated blocks or on unsprayed blocks.

In nearly every test with DDT more than 99 per cent control was obtained of adult leafhopper. No nymph populations developed in the sprayed areas for several weeks after treatment. The population of leafhoppers in the vineyards remained very low for periods of from 30 to 90 days. —9-21-46.

The Effect of Sublethal Dosages of Tartar Emetic on the Mexican Fruitfly[1]

C. C. PLUMMER and E. W. BAKER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[2]

Experimental work in citrus groves has shown that populations of the Mexican fruitfly, *Anastrepha ludens* (Loew), as measured by traps, may be considerably reduced by the application of sweetened sprays containing tartar emetic (Plummer *et al.* 1943, Baker *et al.* 1944). Since the flies are in no way forced to consume sweetened insecticides sprayed or dusted on the foliage of the trees, it is supposed that more often than not they ingest only sublethal amounts. The data here presented were obtained in an effort to determine the effects of sublethal dosages of tartar emetic on *A. ludens.*

Allman (1940) presented data on the Queensland fruitfly, *Dacus ferrugineus* F., which led him to state: " . . . both tartar emetic and sodium fluosilicate exercise some metatoxic or after effect and flies surviving toxicity tests in which these poisons are used actually deposit a number of sterile eggs." In more extensive experiments Marlowe (1945)[3] found that sublethal dosages of tartar emetic had a definite effect on the number and viability of eggs deposited by the melonfly, *D. cucurbitae* (Coq.). The present authors conducted two laboratory experiments with *Anastrepha ludens* to obtain a better understanding of what may occur in the field.

Casein was added to the usual laboratory diet of the flies to stimulate egg production. In previous work with Mexican *Anastrepha fraterculus* (auct.), the junior author found that, when casein was added to the diet of granulated sugar and cut orange for 24 days following the flies' emergence, the percentage of developed ovaries was much higher, and J. G. Shaw[4] reported that the addition of casein to sugar and cut orange appeared to stimulate egg production of *A. serpentina* (Wied.).

On the contrary, when Shaw restricted the diet—beginning a day or two after emergence—to sugar and casein, no eggs were laid between the thirty-third and sixty-second days. Since no records on oviposition were made before the thirty-third day, nothing is known about possible egg production prior to that time. In those tests 120 flies of each sex were used, and the diet consisted of 9 parts of sugar to 1 part of casein. Somewhat similar results were obtained by the junior author, who found that, when Mexican *Anastrepha fraterculus* flies were restricted to a diet of casein and sugar in the proportion of approximately 1 part to 10, not only was there no oviposition, but all the flies (100) were dead at the end of the twenty-fourth day.

In the experiments reported in this paper, where adults of *Anastrepha ludens* were fed sugar and orange for 20 to 31 days after emergence and were then restricted to a diet of sugar and small amounts of casein (¼ pound per 100 gallons), altogether different results were obtained. The flies appeared to oviposit normally, as did those fed on sugar alone. It appears logical, therefore, to compare results of experiments in which flies were fed on sugar alone, on sugar and casein, and on similar diets to which different amounts of tartar emetic had been added.

EXPERIMENT 1.—Methods described by Plummer (1943) for the testing of insecticides were followed with slight modification. Five cages, each containing 25 flies of each sex, comprised a series for testing the different combinations of materials at a constant temperature of 25° C. and relative humidity close to 60 per cent. Flies were 21 to 31 days old at the beginning of the experiment. Flies in each series had constant access to one of the following combinations of materials, the amounts for 100 gallons of aqueous solution being as follows: (1) 1 ounce of tartar emetic, 20 pounds of granulated sugar, and 4 ounces of casein; (2) 0.5 ounce of tartar emetic, 20 pounds of granulated sugar, and 4 ounces of casein; (3) 20 pounds of granulated sugar, 4 ounces of casein; and (4) 20 pounds of granulated sugar. All casein passed a No. 325 sieve. Flies in another series were given sugar

[1] This study was conducted in cooperation with the Secretaría de Agricultura y Fomento, Mexico.

[2] The authors are grateful to F. M. Wadley, of this Bureau, for advice on the application of statistical methods of analysis.

[3] Unpublished reports.

[4] Unpublished reports.

and casein, except for a 3-hour exposure every third day to sugar-casein preparations containing 2 pounds of tartar emetic in 100 gallons of solution. This series was discontinued because of the high mortality.

One hollow section of skin from partially ripened peach, fastened to glass by means of paraffin, was introduced into each cage at 11:30 a.m. and allowed to remain there until 6 p.m. in order to obtain eggs. For about 2 hours prior to their introduction into experimental cages, the sections had been held in a cage containing only males of *Anastrepha ludens*, so that the flies would clean the skins of any food materials that might be present. Eggs were removed from each section and held on moistened black filter paper in stender dishes at 25° C., to obtain records on viability.

The flies deposited some eggs on the glass, cloth, and framework of all cages, although peach skins were periodically available for oviposition. The same habit was also observed in experiment 2, where flies had constant access to mango skins. Presumably, this common habit of depositing eggs on material other than available fruit was not modified by the diets given the flies. Such eggs could not be recovered. At times a high percentage of the newly deposited eggs were in a state of collapse. These facts are considered in analyses of the data.

The mortality of the flies was recorded when fruit sections were introduced and again when they were removed from the cages. Dead flies were replaced with living flies taken from the two extra cages in each series. Flies in the extra cages were from the same cultures and were subject to the same treatments, including exposure to peach skins, as those in test cages. The numbers in the test cages were checked at intervals.

The mortality of the flies exposed to the 1- and ½-ounce strengths of tartar emetic was so rapid that the poison was eliminated from all diets in the tests started September 1 (Table 1). From September 4 until the experiment was discontinued on October 19, no eggs were deposited in peach skins held in cages where flies had previously been exposed to the 1-ounce strength of tartar emetic. The exposure of flies to small amounts of tartar emetic and casein for approximately 21 days apparently inhibited oviposition by the few surviving females during a subsequent period of 45 days (Table 1). The mortality of flies exposed to the 0.5-ounce strength of tartar emetic was less rapid. Some eggs were deposited in each of the 14 exposure periods following the elimination of tartar emetic from the sugar-casein diet, and a few viable ones were deposited in 4 of the periods. The difference in the number of females in the two series, as well as in the concentration of tartar emetic, might account for some of the differences in results.

More females survived in cages of the two series in which tartar emetic was not included in the diet. In every one of the 19 exposures eggs were deposited in peach skins by flies having access to a diet of sugar and casein, and in all but 2 exposures by flies given sugar alone (Table 1).

The number of eggs deposited in all cages during the first 5 fruit-exposure periods was sufficient for analysis of variance. The number of eggs laid in fruit skins in each cage was corrected for 25 females. It was found necessary to round off the numbers to eliminate fractions, to add 0.5 to the value for each cage, and then to extract the square root before making an analysis of variance. Similar procedures were followed with the second group of 6 exposure periods, except that only 4 cages were available for each of 3 treatments. The number of eggs laid by the few surviving females on the diet that included 1 ounce of tartar emetic was insufficient to permit analysis of the data. More eggs were laid by flies exposed to diets that did not include tartar emetic than by those given that material, and both groups of exposures show highly significant differences between the means for sugar alone and those for sugar-casein preparations containing tartar emetic. No significant difference is shown between the number of eggs laid by flies exposed to sugar-casein and those exposed to sugar alone.

Data from the same cages and the same 2 groups of exposure periods were used in analysis of variance of the angle of percentage (Snedecor 1940) hatch and also the angle of percentage of collapsed eggs deposited in skins of fruit in each cage.

Table 1.—Egg deposition and hatch from Mexican fruitflies exposed to four different diets. All diets contained 20 pounds of granulated sugar, two contained 4 ounces of casein, and two contained tartar emetic, all amounts per 100 gallons of solution.

Exposure Date 1942	Sugar, Casein, and 1 Ounce of Tartar Emetic				Sugar, Casein, and 0.5 Ounce of Tartar Emetic			
	Number of Eggs			Number of Females	Number of Eggs			Number of Females
	Total	Collapsed	Hatched		Total	Collapsed	Hatched	
Aug. 14	104	0	69	126	145	0	127	125
17	43	33	5	126	83	0	45	125
20	92	39	24	124	50	1	43	124
26	69	39	23	108	25	7	5	125
29	46	11	28	79	19	6	3	123
Sept. 1[1]	14	0	12	45	15	12	0	121
4	25	0	22	36	0	—	—	100
7	0	—	—	26	1	0	0	86
10	0	—	—	25	6	2	0	74
13	0	—	—	20	12	8	0	68
16	0	—	—	17[2]	21	0	10	60
19	0	—	—	13	8	0	8	55
22	0	—	—	10	0	—	—	49
25	0	—	—	8	0	—	—	35
28	0	—	—	6	0	—	—	29
Oct. 1	0	—	—	6	0	—	—	24
7	0	—	—	6	0	—	—	19
13	0	—	—	5	1	0	1	14
19	0	—	—	5	7	0	3	12
	Sugar and Casein				Sugar Only			
Aug. 14	173	0	158	125	131	0	85	127
17	135	0	103	124	146	0	66	127
20	128	0	107	125	187	2	125	125
26	119	23	81	125	148	2	88	125
29	88	17	61	125	152	11	93	125
Sept. 1	86	11	62	125	97	26	65	125
4	125	32	65	125	120	22	58	124
7	172	41	92	125	123	30	74	125
10	94	26	51	125	101	39	52	124
13	88	24	34	125	85	22	43	125
16	85	13	38	120	70	22	32	118
19	97	18	57	109	27	6	14	107
22	81	9	58	99	23	3	18	90
25	22	0	13	85	18	0	12	71
28	38	34	3	79	15	5	10	60
Oct. 1	18	0	2	72	16	7	9	54
7	7	0	2	59	0	—	—	42
13	24	0	18	39	8	0	6	29
19	14	0	6	25	0	—	—	20

[1] Tartar emetic eliminated from diet.
[2] No males survived after this date.

The disproportionate number of records in these analyses made it necessary to follow the method of unweighted means (Snedecor 1934, 1940). Analysis of variance of proportionate numbers, *i.e.*, standard analysis, was followed, to obtain the mean square of the variance between cages. This value was multiplied by an average frequency weight to obtain the experimental error for each analysis.

The data for the first 5 exposures show that the mean angle of percentage hatch was greatest when flies had access to a sugar diet containing casein, the difference between that diet and sugar alone being significant. The mean angle of percentage hatch was lowest when 1 ounce of tartar emetic was added to the sugar-casein diet, and differences between that diet and sugar alone are highly significant. In the second group of 6 exposures the mean angle of percentage hatch was about the same for diets of sugar-casein and sugar alone, while the mean for a diet of sugar-casein containing 0.5 ounce of tartar emetic was greatly reduced. Differences

between the latter diet and the sugar-casein or the diet of sugar alone are highly significant.

In the first 5 exposures higher mean percentages of collapsed eggs were deposited by flies exposed to diets containing tartar emetic than by flies not given that substance. Only the differences between the mean for flies on a diet of sugar alone and that for flies exposed to a sugar-casein diet with 1 ounce of tartar emetic are highly significant. Differences between sugar-casein and sugar alone are not significant. In the next 6 exposures analysis of variance shows that there is no significant difference between treatments, and none between the means for the different treatments.

EXPERIMENT 2.—In experiment 1 so many flies died when exposed to concentrations of 1 and 0.5 ounce of tartar emetic that another experiment was undertaken, in which tartar emetic was used at rates of 0.25 and 0.125 ounce, in 100 gallons of aqueous solution containing 20 pounds of granulated sugar and 4 ounces of casein. Treatments again included sugar with casein and also sugar alone. Four cages, each with 25 twenty-day-old flies of each sex, were assigned at random to each treatment, as were 4 additional cages containing flies for replacements. Flies of each cage were permitted constant access to a hollow section of mango skin, which was changed daily. The mango skins were washed in water, but were not exposed to males of *Anastrepha ludens* prior to introduction into the experimental cages.

Individual-cage data were transformed in the same manner followed in experiment 1. Replacements were sufficient to take care of the flies that died during the first 30 exposure periods, and data from the four cages of each treatment could be used in analyses. Data from the next 6 exposure periods, *i.e.*, from May 12 to 17, were taken from three cages in each of four treatments. This limitation became necessary on account of the increased mortality of flies that were exposed to 0.25 ounce of tartar emetic.

Data on the number of eggs laid, in terms of $\sqrt{n+0.5}$, show that differences between treatments and between exposures, and the interaction of treatments and of exposures, are all highly significant (Table 2). The treatment means for the 30 exposures, and also most of the means for the 30 exposures divided into 5 groups, show that significantly fewer eggs were laid by females that had access to diets containing small amounts of tartar emetic (Table 3) than by females whose diets did not include tartar emetic. Significant differences between the diet of sugar alone and one of the sugar-casein diets containing tartar emetic do not appear, however, until the data of group 2 are considered—7 to 12 days after the start of the experiment. Flies given casein and sugar generally laid fewer eggs than flies given sugar alone, but only in the fourth group of exposures are such differences highly significant (Table 3). Analysis of variance of data from 6 fruit-exposure periods extending from May 12 to 17 show highly significant differences between treatments only (Table 2). Fewer eggs were laid by flies exposed to sugar-casein, and also by flies exposed to the 2 sugar-casein diets containing tartar emetic, than by flies exposed to sugar alone. The differences between the data from the diet of sugar alone and those from each of the other 3

Table 2.—Analysis of variance of data of experiment 2. Egg deposition and hatch from Mexican fruitflies fed low concentrations of tartar emetic.

EXPOSURES	SOURCE OF VARIATION	MEAN SQUARE
	Number of eggs in terms of $\sqrt{n+0.5}$	
30 (April 12 to May 11)	Treatment (3)[1]	66.41*
	Exposure (29)	28.59*
	Treatment-exposure (87)	2.10*
	Within subclasses (error) (860)	4.39
	Total (479)	
6 (May 12 to 17)	Treatment (3)	17.41*
	Exposure (5)	2.27
	Treatment-exposure (15)	2.26
	Between cages (error) (48)	2.76
	Total (71)	
	Angle of percentage hatch of eggs	
28 (April 13 to May 11)	Treatment (3)	1180.92*
	Exposure (27)	391.15*
	Treatment-exposure (81)	99.52
	Experimental error (301)	101.00
	Total (412)	
	Angle of percentage of collapsed eggs	
28 (April 13 to May 11)	Treatment (3)	1071.22*
	Exposure (27)	283.97*
	Teeatment-exposure (81)	96.65
	Experimental error (301)	88.62
	Total (412)	

[1] The number of degrees of freedom for each source of variation is given in parentheses.
* Highly significant difference, $P<0.01$.

treatments are highly significant (Table 3).

Individual-cage data on the percentage hatch and the percentage of collapsed eggs are available for only 28 exposures in the first analysis, owing to the lack of eggs under one treatment of the first exposure and to the desiccation of eggs deposited during the eighth exposure. This has precluded the presentation of treatment means for 5 groups, each with 6 exposures. the 6 exposures from May 12 to 17 are too fragmentary for analysis of variance.

The marked effect of sugar and casein diets with 4 different concentrations of tartar emetic, ranging from $\frac{1}{8}$ to 1 ounce in 100 gallons of solution containing sugar and casein, in reducing the number of eggs laid and the percentage of hatch leads to the belief that the field control of *Anastrepha ludens* in northeastern Mexico may have been more effective than had

Table 3.—Mean values and significant differences between means of data of experiment 2. Egg deposition and hatch from Mexican fruitflies fed low concentrations of tartar emetic in a diet containing 20 pounds of sugar and 4 ounces of casein per 100 gallons of solution.

	Mean Value				Significant Differences[1]	
Exposures	Sugar, Casein, and 0.25 Ounce of Tartar Emetic	Sugar, Casein, and 0.125 Ounce of Tartar Emetic	Sugar and Casein	Sugar Only	P<0.05	P<0.01
			Number of eggs in terms of $\sqrt{n+0.5}$			
30 (April 12 to May 11)	3.76**	4.82**	5.03	5.52	0.53	0.70
Group 1	3.09	4.21	4.33	3.77	1.21	1.61
Group 2	5.42**	6.49	6.21	6.80	.83	1.09
Group 3	4.76**	6.34	6.22	6 83	.74	.99
Group 4	3.21**	4.07**	4.63**	5.81	.81	1.08
Group 5	2.31**	3.00**	3.77	4.39	.75	99
6 (May 12 to 17)	1.37**	2.01**	3.04**	3.55	.37	.49
			Angle of percentage hatch of eggs			
28 (April 13 to May 11)	52.81**	57.27**	66.15	65.23	—	—
			Angle of percentage of collapsed eggs			
28 (April 13 to May 11)	20.93**	13.70*	8.04	7.80	—	—

[1] Numerical differences for angle data not listed, since, because of disproportionate numbers, it is necessary to compute *t* for each comparison. This was done only for differences between the mean for sugar without casein and each of the treatment means.
* Significant difference when compared with the mean for sugar without casein.
** Highly significant difference when compared with the mean for sugar without casein.

It is shown (Table 2) that differences between treatments and also between exposures are highly significant for both the angle of percentage hatch of eggs and the angle of percentage of collapsed eggs. Differences between means show that lower mean angles of percentages of eggs hatched and higher mean angles of percentages of collapsed eggs were occasioned by the inclusion of small amounts of tartar emetic in the sugar-casein diets of the flies (Table 3). These differences are significant, as compared with the means for sugar alone. Data on the percentage hatch and the percentage of collapsed eggs for

been indicated by trapping with glass traps (Plummer *et al.* 1943). Tartar emetic sprays were first applied on small plots of citrus at Hacienda de Santa Engracia, Tamaulipas, early in 1936 (Baker *et al.* 1944), and thereafter larger plots were sprayed with it for 6 successive seasons at the relatively high rate of 4 pounds in 100 gallons of solution containing 20 pounds of granulated sugar. After the first season the population of fruitflies was, with a few brief exceptions, generally reduced during all 6 seasons. Naturally, many factors influence the size of the fly population, but some of the reduction

may have been due to the ingestion of sublethal dosages of tartar emetic and other insecticides by the fruitflies. Furthermore, it is likely that the ingestion of small amounts of tartar emetic by newly emerged flies would be even more pronounced than shown in these studies with mature fruitflies.

SUMMARY.—Laboratory studies on the Mexican fruitfly, *Anastrepha ludens* (Loew), considered the number of eggs laid, the percentage hatch of eggs, and the percentage of collapsed eggs when mature flies were exposed to the following diets: (1) 20 pounds of granulated sugar in 100 gallons of solution, (2) the sugar diet with 4 ounces of casein added, (3) the sugar-casein diet with 1 ounce of tartar emetic, and (4) the sugar-casein diet with 0.5 ounce of tartar emetic. Flies that ingested diets containing tartar emetic laid significantly fewer eggs than flies not given that material. Flies exposed to a diet including 1 ounce of tartar emetic for 21 days failed to lay any eggs in fruit sections for 45 days. However, flies whose diet included 0.5 ounce of tartar emetic did lay a few eggs, some of which were viable. The percentage hatch of eggs was lower, but the percentage of collapsed eggs was higher when tartar emetic was included in the diet. In general, the addition of casein to the sugar diet had little or no effect on number and viability of the eggs deposited.

In a second experiment the amounts of tartar emetic included with sugar and casein were reduced to 0.25 and 0.125 ounce, and essentially similar results were obtained from these two diets, although the reduction in the number of eggs deposited was not so marked as with the diet containing 1 ounce of tartar emetic.

A discussion is given of the possibility that the ingestion of small amounts of tartar emetic sprays by flies in the field might be a factor in the general reduction of the fly population in the vicinity of Hacienda de Santa Engracia, Tamaulipas, Mexico, from 1936 to 1942.—10-15-46.

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U.S. NAVY COMMENDS BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

The Journal of the American Medical Association, Volume 131, Part 2, page 145, 1946, carried the following item:

"The Bureau of Entomology and Plant Quarantine of the Department of Agriculture was recently commended by Secretary of the Navy James Forrestal and Vice Admiral Ross T. McIntire, Surgeon General of the Navy, for research conducted in the development of insect and mite repellents.

"In a letter to the Secretary of Agriculture, Secretary Forrestal stated that the Bureau of Entomology and Plant Quarantine 'rendered a fundamental and outstanding contribution to naval forces which has changed the entire methodology in the control of insect borne diseases.'

"Vice Admiral McIntire, in letters of commendation to Dr. P. N. Annand, Chief of the Bureau, and thirty-two of his associates, said that the immediate recognition of the great military potentialities of insecticides, such as DDT, aerosols, insect repellents and protective fabrics, resulted in their conversion to maximal efficiency for military use.

"The close cooperation and assistance rendered the Navy by the Bureau of Entomology and Plant Quarantine were in a large measure responsible for the successful development of the repellents which made it possible to carry on our military campaigns in tropical areas with a freedom from disease formerly thought impossible, the Surgeon General pointed out."

Soil Insecticides for Control of the Southern Corn Rootworm[1]

B. B. Fulton,[2] *North Carolina Agricultural Experiment Station, Raleigh*

The successful use of DDT as a soil insecticide for the control of Japanese beetle larvae prompted some experiments along the same line for the control of southern corn rootworm, *Diabrotica duodecimpunctata* Oliv. The results of small plot experiments in 1946 with DDT and hexachlorocyclohexane give promise of a practical means of protecting young corn plants from the southern corn rootworm, either by mixing the insecticide with the fertilizer or by adding the insecticide to the soil by some device during the fertilizing or seeding operation. In some of the tests hexachlorocyclohexane caused plant injury, so that DDT appears to be the more promising of the two insecticides for this purpose.

A poorly drained field at Raleigh was used for the experiment, and an abundant rainfall made conditions ideal for severe rootworm injury. On April 6, 1946, four rows, about 100 feet long, were planted with hybrid sweet corn, and on April 16, four more rows (rows 5 to 8, Table 1) were planted. The corn was planted in hills two feet apart and with four seeds in each hill. Previous to planting, rows 1, 2, and 6 were prepared by dropping 5 to 7 grams of 3 per cent DDT dust at each hill and stirring it into the soil with a hoe. The seed was planted in and covered with the treated soil. Part of row 4 was treated in a similar manner with about one gram per hill. The other part of row 4 received no soil treatment but was planted with seed coated with 3 per cent DDT by shaking the seed and dust together in a jar. Row 8 was prepared at the same time as row 6, and in the same manner, but with a dust containing 85 per cent sulphur and 4.7 per cent hexachlorocyclohexane of which 18 per cent (0.8 per cent of total) was the gamma isomer. Rows 3, 5, and 7 were untreated.

The germination was quite uniform and little difference could be noted between the treated and check rows until the plants were about two inches high. From then on the plants in the check rows were noticeably retarded in growth due to rootworm injury. Many plants were killed while small and others had the central leaves or bud killed but continued to survive and put out "suckers" from the base. Check row plants which showed no definite symptoms of rootworm injury were generally smaller than the average of the treated rows. Treated rows did not escape injury entirely but the number of injured plants was much smaller.

On May 11, when the rootworm injury appeared to have reached a maximum, the plants were inspected and counted. The results are given in table 1 as the average number of uninjured plants per hill, four being the highest possible number with perfect germination. Some rootworm injury continued to show up for a week or two later, so another inspection was made on June 7 after the hills had been thinned to 2 plants per hill. The results taken on this date are also given in table 1 in terms of the percentage of hills with one or two good plants likely to produce ears. The results from check row 3 were computed as a whole for comparison with rows 1 and 2 and also in two parts for comparison with the adjacent parts of row 4. The photograph of rows 5 to 8 (Fig. 1) shows that the difference in appearance of the rows was even more striking than the figures indicate, due to the greater average size of the plants in the treated rows.

Table 1.—DDT and hexachlorocyclohexane as soil insecticides at planting time for control of southern corn rootworm, in two plantings of hybrid sweet corn.

Row	Treatment—Amount Used per Hill	May 11 Average Number of Uninjured Plants per Hill	June 11 Percentage of Hills Likely to Produce Ears
1	5 to 7 grams, 3% DDT	2.7	95
2	Ditto	3.0	99
3	Check, whole row	1.1	46
4a	Seed coated with 3% DDT	1.9	63
3a	Check adjacent to 4a	.7	33
4b	1 gram, 3% DDT	2.7	100
3b	Check adjacent to 4b	1.7	62
5	Check	1.8	50
6	5 to 7 grams, 3% DDT	3.2	88
7	Check	1.2	40
8	5 to 7 grams of 4.7% hexachlorocyclohexane	2.4	88

[1] Contribution of the department of Zoology and Entomology, North Carolina Agric. Experiment Station. Published with the approval of the Director as Paper No. 250 of the Journal Series.

[2] Professor of Entomology.

The small amount of 3 per cent DDT dust deposited on the seed in the half row 4a apparently gave some protection from rootworms. The use of 1 gram per hill as in half row 4b gave as good a stand of corn as the rows receiving 5 to 7 grams per hill. Possibly this would not have been true if the infestation had not been lighter in that part of the field as indicated by the adjacent portion of the check, 3b. Further experiments would be necessary to determine the minimum amount required for effective control. The amount used per acre, computed on the basis of rows 3.5 feet apart, would be about 2.5 pounds of pure DDT in rows 1, 2, and 6 and about

FIG. 1.—Control of southern corn rootworm on sweet corn by soil insecticides. Row 5 to 8 (see Table 1) are shown, reading left to right. The other rows (unlabelled) are field corn, not part of this experiment.

0.5 pound in the half row 4b. The material, however, was concentrated in a relatively small portion of the total soil area, probably about 7 per cent.

In a second experiment in rootworm control, the materials were applied as a spray after the plants were 2 or 3 inches high. This corn was planted in hills on May 13, when no more rootworm injury was expected. However, rootworm injuries began to appear soon after the corn came up. On May 24, two spray mixtures were applied with a compressed air sprayer using a solid stream nozzle with a thirty-second of an inch opening. In rows 1 and 3, the nozzle was pressed into the soil between the plants so as to inject about 100 cc. around the roots of the plants. In rows 4 and 6, the liquid was squirted on the soil surface about the plants for a few seconds, using about 50 cc. per hill. The mixture used on rows 1 and 4 contained 5 grams per liter of a dry powder containing 50 per cent hexachlorocyclohexane and 5 per cent gamma isomer. The spray used on rows 3 and 6 contained 5 grams per liter of wettable powder containing 50 per cent DDT.

The results taken on June 7 are shown in Table 2. Since the number of seed planted per hill was not counted in this planting, the results are given in terms of the percentage of existing plants showing rootworm injury. The two materials gave about equal control and the larger amount somewhat better control in each case. Considering that a small amount of rootworm injury had been caused before the materials were applied, it seems probable that further damage was stopped entirely in rows 1 and 3. The estimated rate per acre in terms of the pure chemicals is 3.4 pounds for rows 1 and 3, and 1.7 pounds for rows 4 and 6. The method has possibilities for garden corn when rootworm injury is detected soon after germination.

No injury due to the insecticide was noted in any of the experiments described. The corn plants in all the treated rows grew vigorously and in general were better plants than in the check rows. However, in an experiment at Laurinburg, N. C. on

Table 2.—Results of applications of dilute suspensions to the soil around young corn plants after rootworm injury had started to appear.

Row	Insecticide, Approximate Amount per Hill and Method of Application	Percentage of Plants Showing Rootworm Injury
1	Hexachlorocyclohexane 100 cc., injected	6.4
2	Check	32.2
3	DDT, 100 cc., injected	6.1
4	Hexachlorocyclohexane 50 cc. on surface	11.9
5	Check	17.7
6	DDT, 50 cc. on surface	11.2
7	Check	36.1

May 9, field corn planted in soil treated with hexachlorocyclohexane showed definite insecticide injury. The mixture used was the same as in the first experiment at Raleigh, the only differences in the two treatments being in the seed used, the type of soil and probably the soil temperature.

Since the hexachlorocyclohexane dust

used in the experiments contained 85 per cent sulphur, another experiment was started on June 18 to compare the phytotoxic action of this dust with a similar dust in which the sulphur was replaced with pyrophyllite. The new dust contained a larger portion of total hexachlorocyclohexane (8 per cent) but the same amount of gamma isomer (0.8 per cent). Treatments with sulphur alone and with 3 per cent DDT dust were also included in the experiment. All treatments were applied at the same dosage as in the original experiment and repeated with double that amount. Hybrid sweet corn and the field corn used in the Laurinburg test, were planted in alternate hills, using 5 seeds per hill.

The corn was examined 10 days after planting. The plants in the rows treated with sulphur and DDT appeared equal in size to those in the check row. Actual counts showed 97 per cent germination in the check, 95 per cent in row having the double dosage of DDT and 98 per cent in the other DDT row and the two sulphur rows. On account of the late planting date, no rootworm injury was present. All rows treated with hexachlorocyclohexane showed definite signs of insecticide injury. The plants averaged less than half the size of those in the other rows. Although most of the seed had germinated the number of plants above ground varied from 71 to 83 per cent of the number of seeds planted. The most severely injured plants had all the leaves still in a tight roll. Less severely injured plants were small and their leaves had grown more in width than in length. This experiment shows that under some conditions hexachlorocyclohexane is toxic to young corn plants although it is not known just what those conditions are. Apparently DDT is a much safer insecticide to use for southern corn rootworm control, although further experiments with hexachlorocyclohexane might show that effective control at dosages safe for the plants.—11-2-46.

Effect of Xanthone, DDT, and Other Insecticides on the Pacific Mite

E. J. NEWCOMER and F. P. DEAN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In 1941 and 1942 at Yakima, Wash., it was noted that infestations of the Pacific mite, *Tetranychus pacificus* McG., were much less on apple trees sprayed with xanthone for controlling the codling moth, *Carpocapsa pomonella* (L.), than on adjoining trees sprayed with lead arsenate or phenothiazine (Newcomer 1943). Borden (1944) reported having observed that xanthone used on Bartlett pears and on apples in California controlled the European red mite, *Paratetranychus pilosus* (C. & F.), and the two-spotted mite, *Tetranychus bimaculatus* Harvey. Observations on the effect of xanthone on mites, as well as the effect of lead arsenate, cryolite, nicotine bentonite, and DDT, have been continued in Washington by the writers.

Infestations of the Pacific mite usually reach a peak in August, and the best time to observe the comparative degrees of infestation on trees sprayed with different materials is during that month, when the maximum damage has occurred and the mites are migrating to the trunk of the tree. In appraising the infestation, the method previously used and explained (Newcomer 1943) was employed. In this method the various degrees of infestation are given arbitrary numbers, as follows: 4, a majority of the leaves are covered with webbing and large numbers of mites are migrating to the trunks; 3, large numbers of leaves are covered with webbing and mites are migrating to the trunks in considerable numbers; 2, only small numbers of infested leaves and migrating mites can be found; 1, the infested leaves are very few and there is no migration; and 0, no mites at all can be found after several minutes' search. In computing average figures, decimal fractions have been retained.

In 1944 the reliability of this method was tested by making three successive estimates of the infestation on 135 trees at intervals of a week or 10 days. The second

Table 1.—Average degree of infestation of the Pacific mite in apple trees sprayed with xanthone, DDT, and other insecticides. (Lead arsenate, 2 lb. to 100 gal., was used for the calyx spray in all treatments: the materials listed were used in 6 or 7 cover sprays, except as noted.)

Treatment No.	Treatment (Quantities per 100 Gal.)	1943	1944		1945	
		Aug. 10 Rome	Aug. 16 Rome	Aug. 18 Winesap	Aug. 9 Rome	Aug. 10 Winesap
1	Lead arsenate 3 lb., mineral oil 1 qt.,[1] colloidal spreader 2.67 oz.	2.1	1.4	1.9	1.5	1.9
2	Lead arsenate 1.5 lb., DDT 4 oz., mineral oil 1 qt.,[1] colloidal spreader 2.67 oz.	—	—	—	1.8	2.0
3	Cryolite (90%) 3 lb., mineral oil 1 qt.,[1] colloidal spreader 2.67 oz.	1.9	1.3	1.9	1.6	1.3
4	Cryolite (90%) 1.5 lb., DDT 4 oz., mineral oil 1 qt.,[1] colloidal spreader 2.67 oz.	—	—	—	2.1	2.0
5	Xanthone 2 lb., kerosene or stove oil 1 qt., colloidal spreader 8 oz.[2]	1.3	1.0	1.0	1.0	1.0
6	Xanthone 1 lb., DDT 4 oz., stove oil 1 qt., colloidal spreader 8 oz.[3]	—	—	—	1.3	1.1
7	Nicotine bentonite (1:5) 3 lb., mineral oil 1 qt.,[1] oleic acid 0.25 pt., aluminum sulfate 2 oz.	2.0	1.4	1.3	2.0	1.5
8	Nicotine bentonite (14% nicotine) 2 lb., mineral oil 1 qt.,[1] oleic acid 0.25 pt., aluminum sulfate 2 oz.	—	—	—	1.9	1.0
9	Nicotine bentonite (14% nicotine) 1 lb., DDT 4 oz., mineral oil 1 qt.,[1] oleic acid 0.25 pt., aluminum sulfate 2 oz.	—	—	—	2.4	2.0
10	DDT 8 oz., pyrophyllite 1 lb.	—	4.0	4.0	3.3	—
11	DDT 8 oz., pyrophyllite 1 lb., mineral oil 1 qt., colloidal spreader 2.67 oz.	—	3.0	—	—	—
12	DDT 8 oz., pyrophyllite 1 lb., dinitro-*o*-cyclohexyphenol, dicyclohexylamine salt (20%) 8 oz. (in 4th cover spray), 5.3 oz. (in 5th cover spray)	—	—	—	1.0	—
13	DDT 4 oz. dissolved in benzene 225 ml. and then in mineral oil (emulsible) 2 qt.	—	—	—	2.3	—
14	DDT 2 lb. (5 lb. of 40% wettable powder)	—	—	—	2.0	—
15	Unsprayed (4 trees)	—	1.5	—	—	—

[1] Increased to 2 qt. in 2 or 3 cover sprays.
[2] Nicotine bentonite used as in Nos. 7 or 8 in 1st and 2d cover sprays.
[3] Nicotine bentonite and DDT used as in No. 9 in 1st and 2d cover sprays.

and third estimates were made without referring to the previous estimates. Because of the number of trees involved and the interval between estimates, it would hardly be possible to remember the classification previously given any individual tree. This study showed that 13 per cent of the trees had been given a lower classification at the time of the second or third examination than previously, 16 per cent had been given a higher classification, and 71 per cent had been given the same classification. Since there had been a gradual increase in the infestation during the period, it is improbable that errors of any consequence were made in classifying more than 13 per cent of the trees, and since in most cases a treatment included 8 trees, which were averaged, such a percentage of error would not be serious.

Table 1 shows the degree of mite infestation on Rome trees sprayed with various insecticides in 1943, and on Rome and Winesap trees similarly sprayed in 1944 and 1945. The averages of the five observations on lead arsenate, cryolite, xanthone, and nicotine bentonite (Nos. 1, 3, 5, and 7) are 1.58, 1.60, 1.06, and 1.64, respectively. These figures show no differences of any consequence between materials except for the xanthone, which results in a consistently lower infestation.

The only time any unsprayed trees were available was in 1944, when there were four Rome trees which had no apples on them and were therefore not sprayed. These trees had an average infestation of 1.5, slightly higher than the figures for trees sprayed with cryolite, lead arsenate, and nicotine bentonite in the same orchard. This figure indicates that, while the mineral oil used with these materials may have some effect on the mites, it does not materially reduce the infestation. The trees sprayed with xanthone, however, were noticeably less infested, and there have never been enough mites on such trees to cause any damage to the crop. There is no evidence that the xanthone kills the mites rapidly, as would oil or dinitro spray; it rather seems in some way to prevent their development. But until more work has been done, no definite reason can be given for the control of mites by xanthone.

The continued use of DDT on apple trees results in a very striking increase in the infestation of mites. In 1944 an average infestation of 4.0 was recorded on both Romes and Winesaps, and even where 1 quart of mineral oil was added the infestation was still 3.0. Similar results were obtained in 1945, although when the dosage of DDT was increased to 2 pounds per 100 gallons (No. 14) the infestation was somewhat less, but it was still too heavy. DDT dissolved in 2 quarts of oil (No. 13) also resulted in a heavy infestation of mites. However a small quantity of an amine salt of dinitro-*o*-cyclohexylphenol added to the DDT in the fourth and fifth cover sprays (No. 12), kept the mites at a minimum.

In treatments Nos. 2, 4, 6, and 9 DDT was used at the rate of 4 ounces to 100 gallons with half-strength lead arsenate, cryolite, xanthone, or nicotine bentonite. In treatments Nos. 2 and 4 the DDT was in the form of wettable powder; in treatment No. 6 a manufactured mixture of xanthone and DDT was used, and in treatment No. 9 a manufactured mixture of nicotine bentonite and DDT. The addition of DDT to the other insecticides was always accompanied by a heavier infestation of mites than where the other insecticide was used without DDT, and usually it was high enough to cause damage. Only where DDT was used with xanthone (No. 6) did the infestation remain low. Apparently the effect of the DDT is to kill or inhibit the development of predators, particularly the ladybeetle, *Stethorus picipes* Casey, and thus allow the mites to become very numerous.

As a check on the method of estimating mite infestation, a modification of the method of Jones & Prendergast (1937) was used in some treatments each year. Samples of 50 or 75 leaves from each of four trees in each treatment were collected, the mites were washed from them with water, the wash water was made up to 500 ml., and after thorough agitation two 10-ml. aliquots were drawn off with a pipette and the mites in the aliquots counted. The average numbers of mites per leaf found in late July or early August are given in table 2, and in general, they agree with the estimates made by the other method.

Table 2.—Average number of Pacific mites per leaf in apple trees sprayed with xanthone, DDT, and other insecticides.

TREATMENT[1]	1943	1944	1945
1	40	28	—
3	—	—	10
5	9	16	11
6	—	—	23
10	—	127	36
12	—	—	5

[1] The treatment numbers are used as in table 1.

In 1945 these collections were made on July 25, just before the fifth cover spray. Dinitro-*o*-cyclohexylphenol was used in treatment No. 12 in both the fourth and fifth cover sprays, and therefore a second examination of Nos. 10 and 12 was made on August 3, 7 days after the fifth cover had been put on. The average number of mites per leaf at that time had increased to 146 in No. 10 and to only 9 in No. 12.

No doubt heavy infestations of mites, if they occur before the end of August, interfere with the normal functioning of the leaves and result in smaller apples and possibly also in reduced color. There was so much variation in color in the orchards used that no reliable estimate of this could be made. There was also considerable variation in size, but the average of a large number of trees in 1945, when there was a fairly heavy crop, gives some evi-

dence of the effect of mites on size. The average number of apples per orchard box picked from 36 trees having a mite infestation rated as 1 was 107; from 65 trees rated as 2, 115; and from 30 trees rated as 3, 136. These trees were grouped without regard to spray treatment. The average number of apples per box from 16 trees given a standard treatment of lead arsenate and summer oil, and having an average mite infestation of 1.5, was 108, and from 16 trees sprayed with DDT and having an average mite infestation of 3.3, 130. Evidently a mite infestation of 1 does not affect the size of the fruit, but greater infestations do.

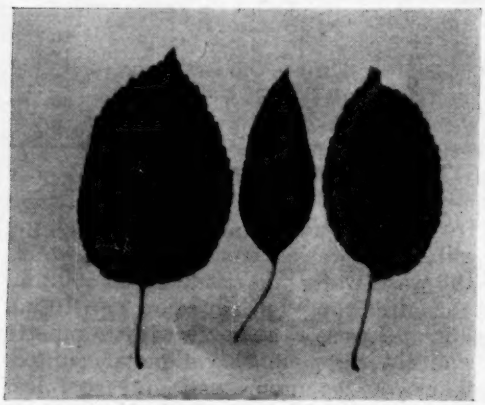

FIG. 1.—Effect of Pacific mites on apple leaves. Left, leaf bronzed; center, leaf bronzed and with dead areas along midrib; right, normal leaf. Leaves at left and center sprayed with DDT; leaf at right sprayed with lead arsenate.

These experiments show that xanthone, as used for controlling the codling moth, definitely prevents the Pacific mite from developing to the point where it causes damage. Infestations do not ordinarily become higher than 1, there is no foliage injury, and the fruit is not reduced in size. DDT, on the other hand, allows a greater development of the mites, resulting in browning or bronzing of the leaves, often with irregular dead areas along the midribs (Fig. 1), and a consequent dwarfing of the fruit. Any mite infestation rated higher than 2 will cause this, and even an infestation of 2 will have some ill effect.

There was no evidence that lead arsenate, cryolite, or nicotine bentonite had any effect on mite infestations. The addition of a small quantity of DDT to half strengths of these insecticides considerably increased the infestation in every case. However, the use of DDT in this manner with xanthone did not increase the infestation to the point where damage occurred. A small quantity of an amine salt of dinitro-*o*-cyclohexylphenol added to DDT in two of the cover sprays also prevented mite damage. The use of 2 quarts of summer oil with DDT, on the other hand, did not prevent mites from developing, and the consistent use of larger quantities of oil would probably result in smaller fruit.

The conclusion from these experiments is that, if DDT were to be used for controlling the codling moth on apples in areas infested by the Pacific mite, definite measures would have to be taken for controlling the mites. This could be done by using the DDT with xanthone, which is a safe procedure, as it has been proved that xanthone will not injure the fruit if used only after the second cover spray, and excellent control of the codling moth has been obtained. If the xanthone is used in the first and second cover sprays, it russets the fruit of Jonathan and of yellow varieties. Mite control could also be obtained by adding a dinitro salt to two or more of the cover sprays, if further trial of this material shows it to be safe. Slight foliage injury was caused by it in 1945. Injury from infestations of the mites would be too severe to allow DDT to be used on apple in this area unless some such measures were taken.—11-29-46.

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Sunflower Seed Weevils and Their Control

A. F. SATTERTHWAIT, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The sunflower is a rugged, cosmopolitan plant yielding 1200 pounds of seed per acre. The seed is a prolific source of an oil that may be substituted for olive oil in foods and confections. Though used as a drying oil in Russia and Argentina, sunflower-seed oil would not replace linseed oil or dehydrated castor oil as a drying oil.[1] In 1933 an American confectioner had 5000 acres of sunflowers in one Cuban planting for the production of oil. During the Second World War sunflower acreage was increased for the production of needed vegetable oils.

Experimentation is under way in the United States to increase the oil content of sunflower seed. The vegetative parts may be used as silage, which is nearly as good as corn silage for the production of beef and milk. In northern latitudes sunflowers are grown in considerable acreages and are used, alone and with oats, for forage and silage. Sunflower seed is popular in some localities as an equivalent of roasted peanuts or popcorn, and is on the market in the form of roasted nut meats. The seed is also used in poultry-feed mixtures and is a preventive of and a cure for beri-beri in birds.

Forbes (1915) stated that in Illinois the production of sunflower seed for oil was stopped because of damage by a seed weevil, later determined to be *Desmoris fulvus* (Lec.). In 1927 members of the Southeast Missouri Cooperative Sunflower Growers' Association grew about 5000 acres of sunflowers. Gardner (1921) reported that the Paint Manufacturers' Association of the United States produced in 1916 approximately 5,000,000 pounds of sunflower seed, which, if yielding the expected 30 per cent of its weight in oil would give about 1,500,000 pounds of oil. A test crush of 100 tons of seed was milled for oil and gave a satisfactory yield. The total amount of sunflower seed produced in 1920 in the United States was 6,500,000 pounds, of which about 70 per cent was produced in southeastern Missouri. The other important producing areas were in southern Illinois and in the San Joaquin Valley, California. In recent years, however, the production in Illinois and Missouri had been almost entirely discontinued until war needs revived interest in this crop. The decline of acreage seemed to be chargeable especially to the sunflower seed weevils. Brief notes on the biology of these weevils and a record of experiments for their control follow.

LIFE HISTORY.—Two seed weevils, *Desmoris fulvus* (Lec.) and *D. constrictus* (Say), are among the worst pests of cultivated sunflowers in the United States. *D. fulvus* has been recorded from Illinois to California and *D. constrictus* from New Jersey to California. *D. fulvus* is about 2.5 mm. long and of bright rufous, or iron-rust, color. *D. constrictus* is slightly larger and is gray. Both are single-brooded, and in Illinois they make their appearance almost simultaneously in midsummer as adults on the new crop of sunflowers. Life-history studies were conducted in southeastern Missouri and central Illinois, chiefly on the genus *Helianthus*, though some other Compositae, obviously hosts of other sunflower insects, were examined. Adults of *D. fulvus* were observed on sunflowers in the field from July 17 to September 29, on hybrid sunflowers on August 1, on Stella sunflowers on July 27, on Jerusalem artichoke from August 5 to 23, and on *Helianthus hirsutus* Raf. on July 27. No species outside of the genus *Helianthus* was found to be attacked by *D. fulvus*.

The adult *Desmoris* weevil punctures the soft hull of the sunflower seed with its mouth parts and feeds on the kernel. The female deposits the eggs singly in some of the excavations. The punctures close tightly, often without leaving an externally visible trace. Specimens of *D. fulvus* eggs measured 0.38 to 0.56 mm. in thickness and 0.45 to 0.66 mm. in length. They are elliptical and white, with a transparent shell. With the development of the embryo, the egg appears translucent and the mandibles and ocelli of the larva may be seen through the shell. The eggs hatch and the larvae feed within the seeds.

Desmoris fulvus passes the winter in the larval stage. Some individuals were ob-

[1] Statement by John C. Cowan, head of Oil and Protein Division, Northern Regional Research Laboratory, Peoria, Ill.

served to remain in that stage nearly 11 months, but the normal larval period is about 10 months. Some of the mature larvae leave the achenes and go to the soil before harvest; others remain within the hull until the following spring or early summer. Pupation normally takes place in the soil, the length of the pupal period being about 8 days. The larvae that cut out of the achenes before harvest, or later while the seed is in storage, leave conspicuous holes, the presence of which greatly reduces the selling price of the seed.

Desmoris constrictus was taken in the adult stage from June 28 to September 21, and mating was observed on August 15 and 31. No eggs of *D. constrictus* were obtained. This species occurred in the commercial sunflower in relatively small numbers, estimated at one *D. constrictus* adult to 20 or 30 *D. fulvus*. No specific characters were recognized by the writer for distinguishing the two species in the larval stage. Larvae left the achenes and entered the soil as early as August 13, but some remained alive throughout the winter in achenes of hybrid sunflowers. Almost all the overwintered larvae in seeds of hybrid double-flowered sunflowers seemed to be *D. constrictus*. The hybrid seeds infested by this species were greatly inflated, but there was no recognizable inflation of the commercial sunflower seed. One larva, removed on August 10, 1934, from a hybrid sunflower seed, remained in the larval stage till July 17, 1935, and subsequently yielded an adult. Some other larvae appeared large enough to be this species, but failed to yield adults. Remains of this species were identified in bin-run commercial sunflower seed. Although larvae found in wild sunflower seeds were not successfully reared, the adults of the two species were associated on the flower heads and it may be assumed that both species breed in the seeds of the wild sunflower.

NATURAL CONTROL.—One hymenopterous parasite, *Microbracon mollitor* Say, was reared frequently from larvae of *Desmoris fulvus* from one locality—Lovington, Ill.—being found in 65 per cent of the heads examined in 1939. The larva of this parasite binds the larval remains of the host to the silken cocoon.

ARTIFICIAL CONTROL.—At present no satisfactory method for the control of these seed weevils is known. With such tall and long-flowering varieties of sunflowers as were in commercial production during 1934 and 1935, insecticidal control seemed impracticable. Experimental trials with calcium arsenate, lead arsenate, sodium fluoride, pyrethrum, talc, hydrated lime, gypsum, and hand picking gave unfavorable results. The chemicals were applied dry, with small hand bellows.

As some larvae fall to the ground before harvest and pass the winter in the soil, fall plowing should afford some control. Crop rotation might aid slightly, as the adult beetles fly freely. The development of hybrid strains may result in plants of medium height and with a short, uniform blooming period. With such plants insecticidal treatment might become practicable. In any event enough apparent resistance to attack by these weevils was observed to warrant an effort to develop resistant strains; therefore experiments were begun in 1936.

RESISTANT VARIETIES.—Seeds of varietal strains of the sunflower *Helianthus anuus* L. were obtained from as many different sources as possible for field tests and were planted at two or more widely separated locations. Open-pollinated seeds were obtained from Missouri and California and also from Argentina, Brazil, Czechoslovakia, France, Germany, Holland, Hungary, Italy, Rumania, Turkey, and the Union of Soviet Socialist Republics. Inbred seeds from Canada were also obtained.

When the plants had matured, the seeds were examined and those from plants showing the lightest infestations were saved for replanting. The selections were to be planted and reselected through a series of years until a strain homozygous for the factors adverse to weevil infestation was established.

In 1936 plots were established at East Prairie, Mo., and Alhambra, Ill. In 1937 these plots were continued and a small trial planting was made at Urbana, Ill. In 1938 the East Prairie and Urbana plots were continued, a plot was established at Lovington, Ill., and a few hills were planted at Oakwood, Ill. In 1939 plots were maintained at Lovington and at Oakwood, and some selections were planted at Urbana. In 1940 a planting was made at Lovington only.

Babcock & Clausen (1927), in discussing the isolation of pure lines from mixed populations, classified the sunflower as a self-sterile species. The present writer's limited experience in attempting to prevent insects from infesting certain sunflower heads by enclosing them in paper bags resulted in complete sterility in those heads. Selection for resistance was therefore begun on the assumption that the sunflower was completely self-sterile and that it would be necessary to establish homozygous lines by sibbing instead of self-fertilization. With mixed populations of unknown genetic factors, the original selections would have to be made on the basis of phenotypic similarity. This procedure would depend on (1) the presence of sufficiently heavy weevil infestation to show a difference in susceptibility, (2) the number of genetic factors for which each of the selected individuals is heterozygous, (3) the number of genetic factors with respect to which the two selected individuals differ, and (4) the number of chromosomes in the species.

During the 1936 and 1937 seasons the work was conducted by controlled cross-pollination or sibbing of bagged half-heads on plants grown from seed taken from heads that were lightly infested the previous year. After a discussion of technique with C. M. Woodworth, of the Department of Agronomy, University of Illinois, in 1937, and before it was learned that selfing was possible, as reported by McRostie (1924) and Hamilton (1926), the plan of splitting heads into halves and bagging one half was followed successfully. The un-bagged half was left exposed to infestation, in order to measure the resistance or susceptibility of the plant. Pollen was transferred by means of a saucer and a camel's-hair brush from the covered part of the head of one selected plant to the covered part of another.

Selfing was used exclusively on the Lovington plot in 1938 and on all subsequent plots. Many selections made in previous years were planted in 1939 for the purpose of attempting this method of breeding. McRostie (1924) and Hamilton (1926) reported on a measure of self-fertility in sunflowers. McRostie stated that the Central Experimental Farm at Ottawa, Canada, had about 10,000 plants that were the result of five generations of self-fertilization. Hamilton stated that after two or three generations several hundred heads were selfed under paper bags, with 15 to 50 per cent set of seed on nearly all.

The method of analyzing infestations varied somewhat from year to year. In 1936 all seeds were winnowed, and exit holes of weevil larvae were counted in all the seed not discarded with the chaff. In 1937 the East Prairie seed was not winnowed, and weevil holes in undeveloped and developed seeds were recorded separately. Care was taken to distinguish between weevil holes and exit holes of other insects. The seed from Alhambra was treated as in 1936. In 1938 the seed was not winnowed but was divided by a Boehm sampler, and one-fourth of the seed from each head was examined. In 1939 the samples were reduced to 100 kernels from each head. The Lovington plots were so heavily infested that nearly all kernels were destroyed in the embryonic stage by the feeding of the adults. The remaining kernels, even when only slightly developed, were 75 per cent infested with larvae. In 1940 winnowing was applied in moderation and a sample of 50 kernels per head was examined.

Variation among the individual plants in intensity of infestation may be due either to inherent differences in the plants themselves or to chance. The lack of uniformly intense weevil infestations was one of the difficulties encountered in these studies. It was apparent that the insurance of significant results requires some dependable method of exposing the heads to infestation, such as the introduction of a fixed number of male and female weevils into the bag covering each sunflower head or half-head. As shown in table 1, infestations of the plots planted in different localities and years ranged from 5 to 99 per cent of plants from which seed examinations were made, and from less than 1 to 75 per cent of all seed examined. Whatever the cause, extreme differences in infestations of individual plants occurred in some years. Selections of seeds from the least damaged, as well as the most seriously damaged, plants were made for the purpose of isolating resistant and susceptible lines and of fixing or intensifying resistance by the application of standard methods of breeding.

The planting at Lovington in 1939 covered a half-acre in a field that had contained 55 acres of heavily infested sunflowers the previous year, and was the only known planting within a radius of 16 miles. For this reason the plots were intensely infested and afforded a particularly good test of resistance. As many as 2130 adult weevils were found on one plant, and weevils were clustered on all sunflower heads containing fresh florets. Although weevil larvae were present in practically all heads examined, only 75 per cent of the seeds not destroyed by the adults were infested. In the 1938 plots in the same field, when the rest of the field was also planted to sunflowers, 99.3 per cent of the plants and 31 per cent of the seeds were infested. Considering the comparative sizes of the areas exposed to infestations in the two years, the increase in percentage of seeds infested from 31 in 1938 to 75 in 1939 was not nearly so great as was expected. Even though the 1939 plots were exposed to an extremely severe infestation, the percentage of seeds infested was only two and a half times that of the previous year and only three-fourths of the possible rate.

Table 2 shows the sources and percentages of seeds infested in selected lines of sunflower families from which selections were made in 1940 for low and high weevil infestations. The "family" record of infestation for the initial year of selection is that of the one selected plant. Compared with the substantial family averages for the duration of the experiment, strains 3, 5, 11, 24, 28, 32, and 33 appear to be relatively resistant, and 11 and 28 particularly so.

The seed in a covered head or half-

Table 1.—Average infestations by *Desmoris* spp. in sunflower plots planted in different localities and years.

Plot	Year	Heads: Number Examined	Heads: Per Cent Infested	Treatment	Seeds: Number Examined	Seeds: Per Cent Infested
East Prairie, Mo.	1936	1042	50	Winnowed	94,079	16
	1937	205	97	Not winnowed	64,434	59
	1938	218	94	Not winnowed	36,412	54
Alhambra, Ill.	1936	774	5	Winnowed	67,711	16
	1937	244	37	Winnowed	150,268	2
Urbana, Ill.	1937	257	29	Winnowed	145,938	<1
	1938	68	53	Not winnowed	14,564	5
Lovington, Ill.	1938	453	99	Not winnowed	174,003	31
	1939	635	99	Not winnowed	53,701	75
	1940	213	58	Winnowed	10,273	8
Oakwood, Ill.	1939	243	49	Not winnowed	23,057	2

Table 2.—Sources of sunflower seed and percentages of seed infested in plants selected for low and high weevil infestation at Lovington, Ill., in 1940.

1940 Selection No.	Source	Alhambra, Ill., 1936	East Prairie, Mo. 1936	East Prairie, Mo. 1937	Urbana, Ill., 1937	East Prairie, Mo., 1938	Lovington, Ill. 1938	Lovington, Ill. 1939	Lovington, Ill. 1940	Average All Lines in Same Family, 1936–40
3	Imported	0	—	15	—	7[1]	—	17[1,2]	3[3]	41
5	Stockton, Calif.	—	2	94	—	—	69[1]	16[1,2]	0[3]	41
11	Hungary, Nyirmada II	—	2	—	0	4[1]	—	5[1,2]	0[3]	33
23	Buenos Aires, Argentina	—	—	—	0	—	4[3]	20[1]	34[3]	33
24	do	—	—	—	0	—	4[3]	12	0	31
26	Chankari, Turkey	—	—	69	—	—	8	16[1]	27[3]	23
27	do	—	—	69	—	—	0	16	90	18
28	Edirney, Turkey	—	—	36	—	16	—	0	1	36
32	Canada Hybrid, S. F. 38-8-70	—	—	—	—	—	—	60[3]	0[3]	68
33	do	—	—	—	—	—	—	96[3]	8[3]	53
34	Canada Hybrid, S. F. 38-8-73	—	—	—	—	—	—	80[3]	60[3]	50
	Average in all plants tested	5	16	59	1	54	31	75	8	—

[1] Infestation rate of exposed half-head.
[2] Progeny of sibs.
[3] Progeny of selfs.

head was largely protected from infestation. Some infestations, however, seemed to be concentrated in bagged heads or in the bagged portions of half-heads. The enclosed entire head from which the seed of selection No. 33 was taken in 1939 is a striking example of this condition.

In general, the descendants of sibbed and of selfed plants were as heavily infested as the open-pollinated varieties, and inherent resistance to the weevils apparently occurred in only a very few lines or individual plants. The most promising line produced during the several years was Selection No. 28, which showed practically no infestation by larvae in 1940, notwithstanding a most intense infestation by adults. The parent variety from which this line descended came from Edirne, Turkey. The head originally selected in 1937 from the plantings at East Prairie, Mo., showed 36 per cent of the seed infested, while the average seed infestation of all the heads examined from the plantings made in that year and that locality was 59 per cent. (See Table 2.) The head selected in 1938 from the second generation showed 16 per cent infestation, while the average of the several sister plants in the same plot was 21 per cent. The head selected in 1939 from the third generation showed no infestation, while the average of the several sister plants in the same plot was 57 per cent. This plant was the second or third to bloom. Examination of 100 seeds from another plant, which bloomed one day earlier, showed 12 per cent infested. Seed of another plant, which bloomed five days later, was 61 per cent infested. Thus the noninfested head would seem to have had some resistance, because so far as the effect of the time of blooming on infestation was concerned, the proportion of seeds infested might be expected to fall somewhere between 13 and 61 per cent.

As shown in table 2, the selection from Nyirmada District II, Hungary, has also been promising. Infestation in 1939 in four progeny of a plant of this selection, sibbed in 1938, ranged from 2 to 7 per cent, averaging 5 per cent, as compared with an average seed infestation of 75 per cent in all plantings. In 1940, at Lovington, five progeny averaged 5.7 per cent infestation, as compared with 8 per cent seed infestation in all plots. From the results of the successive selections it appears that both the Turkey line and the Hungary line possess a material degree of resistance to the seed weevils. Seed of the resistant inbreds was turned over to C. M. Woodworth in 1944 for use in further breeding experiments.

This attempt to find and establish strains of sunflowers resistant to the seed weevils resulted in the apparent isolation of at least two strains definitely resistant to weevils. The technique of halving the heads and controlling pollination by keeping one-half bagged and obtaining a record of infestation in the unenclosed half was found practicable. Self-pollination established a few seeds in most plants in the first generation and more in subsequent selfings. Seed weevils rarely occur in sufficient numbers to infest all nonresistant plants in the experimental plots. Such irregularity in the natural infestation allows too many plants to escape without an adequate test of resistance. The unique infestation of 1939 was the only highly significant one in the experiments conducted by the present author. Therefore, the confinement of a fixed and ample number of both male and female weevils on each bagged sunflower head or half-head appears to be necessary to insure an effective test of resistance or nonresistance in any strain.

SUMMARY.—Larvae of *Desmoris fulvus* (Lec.) and *D. constrictus* (Say) damage the sunflower-seed crop by feeding inside the kernels and making exit holes in the achenes. Both species have only one generation a year. The adults are present in the field from midsummer until late in September, and they lay their eggs singly in the immature sunflower seeds. The larvae soon become full grown, and some leave the seeds to winter in the soil. Others pass the winter within the seeds. Pupation normally takes place in the soil and requires about eight days. Attempts to control these weevils by applying insecticides to the sunflower heads were made in 1934 and 1935 without success. During the years 1936 to 1940 experiments were conducted to find and develop strains of sunflowers resistant to attack by these weevils and then bring into the resistant line or lines other desired qualities. Tests included strains from many countries and were made in widely separated areas in

Illinois. Methods included sibbing and selfing under control and comparing rates of infestation from generation to generation and in covered and uncovered portions of individual heads. Infestations ranged from 5 to 100 per cent of plants and from less than 1 per cent to as high as 75 per cent of the seed. Seven of the strains which had been developed by sibbing and selfing appeared to be relatively resistant, and two of them particularly so.—10-21-46.

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Effect of Lead Arsenate Sprays on the Pecan Weevil and Other Pecan Insects

C. B. NICKELS and W. C. PIERCE,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Spraying experiments to determine the effectiveness of both lead arsenate and cryolite in the control of the pecan weevil, *Curculio caryae* (Horn), were conducted in the field and in the laboratory in central Texas in 1943–45. Observations were also made on the effect of certain treatments on two other insects attacking pecan, the aphid *Monellia* sp. and the pecan nut casebearer *Acrobasis caryae* Grote.

MATERIALS AND METHODS.—The materials tested were acid lead arsenate and natural cryolite (sodium fluoaluminate not less than 90 per cent). Summer-oil emulsion (a commercial emulsion containing 83 per cent of oil) was used as a sticker in certain tests, and a mixture of hydrated lime and zinc sulfate was included in some of the tests as a safener for lead arsenate.

Several toxicity tests were carried on each year in wire-screen cages placed over sprayed and unsprayed pecan branches.

Two varieties of pecan were used for many of the field tests, although in one test it was necessary to use a group of seedling trees. The treatments were applied to single-tree plots and were replicated 8 to 14 times.

The sprays were timed by observations on weevil development. Large numbers of weevils emerge late in August or in September, after periods of heavy rainfall. If observations at such times showed that nuts were being punctured, 10 trees were jarred to determine the numbers of weevils that had emerged. Spraying was done with a power machine, from the ground or from the top of the sprayer, at a pressure of 500 to 600 pounds, a single-head gun being used. The first spray treatment was applied shortly after many of the weevils had emerged, but before many eggs had been deposited. Usually two spray applications were made, about ten days apart.

Two criteria were used in determining the effectiveness of the spray treatments. (1) The numbers of nuts punctured by weevils during the principal period of weevil activity. (Near the beginning of the oviposition period, serially numbered tags were placed on 50 nut clusters of each tree of the varieties Schley and Western. Punctures on Mahan variety were determined by examining approximately the same number of nuts at the end of the period of weevil activity.) (2) The proportion of weevil-infested nuts harvested from each tree used in the tests. (A representative sample of 250 nuts was examined from each tree.)

CAGE TEST.—The wire-screen sleeve cages used in the tests were 8 inches in diameter and 24 inches long. In 1943 and 1944 10 adult weevils (9 females and 1 male) jarred from trees and in 1945 10 females taken from the soil were used in each cage. Nut-bearing branches that had not been sprayed previously were sprayed with the test mixture and the

[1] The junior writer was associated with this project in 1943 and 1944.

cages were then placed over them. The preliminary cage tests in 1943 indicated that lead arsenate had considerable toxicity to the weevils. In 1944 and 1945 more extensive tests were made. The results are summarized in table 1.

The mortality was variable and in some tests not very high. The reduction in the number of feeding punctures ranged from 74 to 97 per cent. The spray material appeared to be repellent to the beetles.

FIELD EXPERIMENTS IN 1943.—Field experiments were carried on at Gustine, Tex. The treatments were replicated 8 times on the Mahan variety and 11 times on the Western. The trees bore a medium

Table 1.—Toxicity of lead arsenate sprays to the pecan weevil, Brownwood, Tex., 1944–45.

SPRAY MATERIALS	QUANTITY PER 100 GALLONS	WEEVILS USED	WEEVILS DEAD	FEEDING PUNCTURES
	Pounds	*Number*	*Per cent*	*Number*
1944. Branches sprayed Sept. 13, examined Sept. 20				
Lead arsenate Lime Zinc sulfate	3 3 1	72	79	71
Lead arsenate Lime Zinc sulfate	6 6 2	75	99	8
None	—	80	13	271
1945. Branches sprayed Aug. 4, examined Aug. 11				
Lead arsenate Lime Zinc sulfate	6 6 2	95	26	12
None	—	100	8	40
1945. Branches sprayed Aug. 14, examined Aug. 28				
Lead arsenate Lime Zinc sulfate	6 6 2	72	71	16
None	—	66	32	53

crop, and the infestation was heavy. Rains caused a 5-day delay in the application of the material, and a considerable number of eggs were deposited in the nuts before this application could be made. The results of these experiments are given in table 2.

FIELD EXPERIMENTS IN 1944.—Since cryolite appeared to have little value, further experiments were restricted to lead arsenate in various mixtures. In 1944 lead arsenate was tested at two strengths—one on the Schley variety, with 14 replications, and one on the Mahan variety, with 12 replications. There was a heavy nut crop, and the weevil infestation was light to medium, because of a nearly com-

Table 2.—Effect of cryolite and lead arsenate sprays on pecan weevil infestation, Gustine, Tex., 1943. (Sprays applied September 6 and 18.)

SPRAY MATERIALS	QUANTITY PER 100 GALLONS	NUTS PUNCTURED DURING SEASON	HARVESTED NUTS INFESTED
	Pounds	*Per cent*	*Per cent*
	Mahan Variety		
Cryolite Oil emulsion	6 2 qt.	73.2	63.9
Lead arsenate	6	46.1	32.5[1]
None	—	79.5	66.6
	Western Variety		
Cryolite Oil emulsion	6 2 qt.	49.5	39.4
Lead arsenate	6	22.7	21.5[2]
None	—	62.4	49.8

[1] Difference from check significant at odds of 19 to 1.
[2] Difference from check significant at odds of 99 to 1.

plete crop failure in 1942. The first spray treatment was applied before any considerable number of eggs had been laid. The rainfall was light and did not greatly reduce the spray deposits. The results of these tests are summarized in table 3.

FIELD EXPERIMENTS IN 1945.—The lead arsenate treatment (6 lb. per 100 gal.) with lime, zinc sulfate, and oil emulsion, was tested in two orchards near Brownwood, Tex. One test was on the Burkett variety and was replicated 14 times. The second test was on seedling pecan trees and was replicated 10 times. The crop was light and the weevil infestation heavy. The results of these tests are given in table 4.

EFFECT OF SPRAYS ON TREES.—In 1943 lead arsenate alone caused slight injury to

Table 3.—Effect of lead arsenate sprays on pecan weevil infestation, Gustine, Tex., 1944. (Sprays applied September 1, 2, and 11.)

SPRAY MATERIALS	QUANTITY PER 100 GALLONS	NUTS PUNCTURED DURING SEASON	HARVESTED NUTS INFESTED
	Pounds	*Per cent*	*Per cent*
	Mahan Variety		
Lead arsenate Hydrated lime Zinc sulfate	3 3 1	8.2	6.3[1]
None	—	24.2	15.9
	Schley Variety		
Lead arsenate Hydrated lime Zinc sulfate	6 6 2	16.0	10.1[1]
None	—	56.1	36.8

[1] Difference from check significant at odds of 99 to 1.

Table 4.—Effect of lead arsenate sprays on pecan weevil infestation, Brownwood, Tex., 1945.

Spray Materials	Quantity per 100 Gallons	Harvested Nuts Infested
	Pounds	*Per cent*
Burkett Variety		
Lead arsenate	6	7.5[1,3]
Hydrated lime	6	
Zinc sulfate	2	
Oil emulsion	1 qt.	
None	—	50.5
Seedling Pecan Trees		
Lead arsenate	6	37.2[2,3]
Hydrated lime	6	
Zinc sulfate	2	
Oil emulsion	1 qt.	
None	—	79.2

[1] Spray applied Sept. 1 and 11.
[2] Spray applied Aug. 27, Sept. 5 and 14. Nicotine sulfate 7 oz. included on Sept. 5.
[3] Difference from check significant at odds of 99 to 1.

several pecan trees at Gustine; however, humid conditions followed the application of the spray. In 1944 and 1945 pecan trees sprayed with lead arsenate in combination with lime and zinc sulfate showed no evidence of injury. This treatment is probably unsafe on pecan foliage, except in semiarid or arid climates.

EFFECT ON ARSENICAL SPRAYS ON APHID INFESTATION.—In one orchard used in the 1945 tests 40 leaflets from 8 check and 8 sprayed Burkett trees were examined on September 10, to determine the population of the yellow hickory aphid *Monellia* sp. An average of 32.5 aphids, were on each leaflet on the check trees, and 112.7 on each leaflet on the trees that received an arsenical-spray treatment on September 1. The difference was significant at the 1-per cent level.

No counts were made that year to determine the aphid population on trees in the seedling grove, but it was observed that after an arsenical-spray treatment on August 27 aphids were much more abundant on the sprayed than on the check trees. Nicotine sulfate was included in the second application (Sept. 5) in this orchard, and may be needed in weevil sprays in order to keep down aphid infestation.

EFFECT OF ARSENICAL SPRAYS ON THE NUT CASEBEARER.—During the winter following each season's tests, observations were made to determine the effect of certain sprays on the abundance of the pecan nut casebearer. Fifty shoots on each of 10 to 12 sprayed trees and on an equal number of unsprayed trees were examined for hibernacula. The records obtained are summarized in table 5.

Table 5.—Effect of lead arsenate sprays, applied early in September, on the hibernating generation of the pecan nut casebearer in central Texas, 1943–45.

Year	Spray Materials	Quantity per 100 Gallons	Pecan Variety	Hibernacula on Shoots: Unsprayed	Hibernacula on Shoots: Sprayed
		Pounds		*Per cent*	*Per cent*
1943	Lead arsenate	6	Mahan	5.0	0.8
			Western	7.1	.8
1944	Lead arsenate	3	Mahan	4.2	.8
	Hydrated lime	3			
	Zinc sulfate	1			
1945	Lead arsenate	6	Burkett	3.0	.4
	Hydrated lime	6			
	Zinc sulfate	2			
	Oil emulsion	1 qt.			

SUMMARY.—Laboratory tests showed that spray applications of lead arsenate caused considerable mortality and a reduction in feeding by the pecan weevil (*Curculio* caryae (Horn)). In the field natural cryolite was ineffective in weevil control. Two spray applications of lead arsenate with and without safeners were moderately effective in protecting pecan nuts in September from injury by the pecan weevil. Lead arsenate alone caused slight injury to pecan foliage in central Texas in 1943, but this material in combination with lime and zinc sulfate caused no injury in 1944 and 1945. Under certain conditions applications of lead arsenate spray may occasionally result in a large increase in the aphid (*Monellia* sp.) population on the trees, and it may be necessary to add nicotine sulfate to control the aphid infestation. Two applications of lead arsenate spray in September to control the pecan weevil effected a large reduction in the abundance of the overwintering population of the pecan nut casebearer.—11-9-46

Sub-Soil Bark Injury from Kerosene Spray

WALTER EBELING, *University of California, Los Angeles*

Kerosene has been used experimentally in the spraying of red scale-infested citrus trees at 10 per cent concentration, derris extractives being added to increase its insecticidal effectiveness (Ebeling 1942). It was found that if depressions in the soil occurred about the trunk so as to cause an accumulation of the run-off spray, too much kerosene was brought into contact with the bark immediately below the soil line. Since the kerosene beneath the surface of the ground could not evaporate freely as it does above ground, it often injured and killed the bark, turning it brown in color. In the case of densely foliaged young trees, a large proportion of the spray flowed down the trunk and soaked into the soil, resulting in the girdling of many trees in semi-commercial trials of 10 per cent kerosene-derris extractives sprays in 1941. This type of injury was avoided by making a mound of soil around the trunk previous to spraying. These mounds were removed soon after spraying.

More recently, experiments have been made with 3 per cent kerosene-DDT sprays in the control of red scale on citrus (Ebeling 1945). It was found that two properly spaced sprays of 3 per cent kerosene, with 2 pounds of DDT dissolved in 3 gallons of kerosene, generally resulted in good control of red scale without the usual adverse effects of the heavier petroleum oil fractions generally used in citrus spraying. However, it was found that even with 3 per cent kerosene, if basins were made around the trunks of the trees, and the trees were excessively sprayed, injured bark might occasionally be found immediately beneath the surface of the soil. On the other hand, it appears that when 3 per cent concentrations of kerosene are used, sub-soil injury can be avoided if the soil is not depressed adjacent to the trunk.

With the exception of the possibility of sub-soil injury to the bark under the conditions mentioned above, kerosene spray apparently can be used in citrus spraying without the adverse effect on the trees and on fruit quality attendant upon the use of the present types of spray oils. Therefore it seemed justifiable to make a study of what it is about the kerosene that causes injury to the bark when evaporation is prevented. Since similar injury is very rarely found when light medium oil is used as a spray, it was presumed that at least to a certain point sub-soil injury increases with decreasing "heaviness" of the petroleum fraction and that in the range of ordinary commercial kerosene the ligher fractions might account for a large part of the injury.

EXPERIMENTAL PROCEDURE.—Through the courtesy of Union Oil Company, 10 cuts distilled from the regular Union Oil kerosene were made available for experiments designed to determine the relation of distillation range of a kerosene fraction to sub-soil bark injury. In table 1 are shown the distillation ranges of the 10 cuts of kerosene. Cuts 1, 2, 3, 6, 8, and 10

Table 1.—Gravity and distillation range of 10 cuts distilled from kerosene and used in sub-soil bark injury tests.

CUT NUMBER	GRAVITY °API	TEMPERATURES (DEGREES F.) AT WHICH DISTILLATION WAS—									
		IBP	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
1	47.8	260	289	294	302	307	313	318	322	327	338	352
2	44.3	336	348	351	354	356	360	364	368	376	390	408
3	43.6	355	383	386	389	392	396	400	407	415	428	440
4	43.5	355	386	388	393	397	400	406	411	420	430	441
5	43.2	382	390	394	396	398	400	404	408	412	424	432
6	42.9	396	404	406	408	410	411	414	416	420	424	430
7	42.3	406	426	427	429	430	432	434	436	438	442	447
8	41.7	425	443	444	446	447	448	449	451	453	456	460
9	41.3	437	460	462	463	464	465	466	468	470	472	476
10	40.9	450	476	479	481	483	484	485	487	488	491	496

were employed in the present experiment.

Basins were made around the trunks of alternate 8-year old Navel orange trees by piling damp soil around the trunks and forming the soil into the proper shape to hold the spray mixture. The basin thus formed gathered much of the spray flowing down the trunks of the trees and caused it to soak into the soil adjacent to the trunk.

Five trees were sprayed with 10 per cent kerosene, using 8 ounces of blood albumin spreader to 100 gallons of spray,

Table 2.—Differences in the injurious effects of various fractions of kerosene to the sub-soil bark of the trunks of orange trees.

Cut Number	Distillation Range (°F)	Per Cent of Circumference of Trunk Having Bark Killed by the Kerosene					
		Tree number					Average
			2	3	4	5	
1	260–352	100	100	100	100	100	100
2	336–408	100	100	100	75	100	95
3	355–428	100	50	66	75	40	65
6	396–424	20	16	8	48	60	30
8	425–460	25	0	0	8	0	6
10	450–496	0	0	0	0	0	0
Kerosene	260–595	75	66	16	100	33	58

and 5 trees were sprayed with 10 per cent concentrations of 6 of the 10 cuts of kerosene supplied for the investigation. The trees were excessively sprayed to insure the filling of the basins formed around the trunks. These basins each held a gallon or more of spray. The sprays were applied January 4, 1946. The soil was removed from around the trunks and the bark was examined on June 17, 1946. By that time, injured portions of the bark were dead and had turned brown. Injured tissue was removed by means of a specially constructed scraper and a visual estimate of the per cent of the circumference of the trunk beneath the original soil line composed of injured bark was made for each tree.

RESULTS.—In table 2 is shown the estimated per cent of the circumference of each tree trunk with bark killed by the kerosene which had run down the trunk and soaked into the ground. It will be noted that with each increase in the "heaviness" of the kerosene cut, as indicated by its distillation range, there was a corresponding decrease in sub-soil bark injury, until at a distillation range of 450° to 496° F. (cut number 10) no sub-soil injury to the bark was found. It can be seen from table 2 that *Union Oil* kerosene was intermediate in its injurious effect between the heavy and the light cuts of kerosene.

Figure 1 shows the relation between the temperature for 50 per cent distillation of the kerosene in the various cuts and the average per cent of the circumference of the trunk beneath the soil line killed by the kerosene. When the 10 per cent distil-

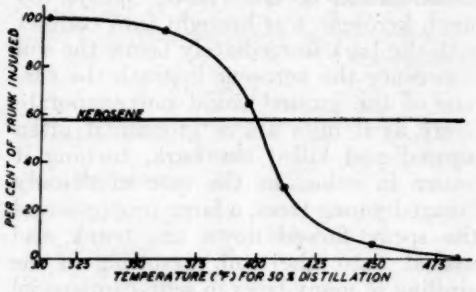

FIG. 1.—The relation of "heaviness" of six kerosene cuts to sub-soil bark injury to orange trees from 10 per cent kerosene sprays.

lation point was used, instead of the 50 per cent distillation point, to show the injury-distillation relationship, a curve was formed of very similar characteristics. This is probably due to the fact that the various cuts have such a narrow distillation range.

It can be seen from table 2 and figure 1 that even under the conditions of excessive spraying and the accumulation of the spray in specially prepared basins to force the kerosene to soak into the tree trunk, little injury was obtained from the kerosene cuts with initial boiling points 425° or higher.

Another experiment was made with the lightest (No. 1) and the heaviest (No. 10) of the kerosene cuts. Ten per cent concentrations were thoroughly shaken in a 5-gallon can and poured into basins surrounding the tree trunks. This time 5 trees were used for each kerosene cut. Again the trees treated with the lighest kerosene fraction were completely girdled and the trees treated with the heaviest fraction suffered no injury whatever.

Ten trees around which basins had been formed were sprayed with 3 per cent kerosene-DDT. The kerosene was a mixture of equal parts of cuts 5, 6, 7, 8, 9, and

10 (see table 1 for distillation ranges). These trees were sprayed December 18, 1945, and examined June 17, 1946. Careful examination of the trunks below the soil line revealed no evidence of injury to the bark. Probably a kerosene with initial boiling point in excess of 375° F., at 3 per cent concentration, would make a spray with a high margin of safety in ordinary commercial citrus spraying.—10-15-46.

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The Oriental Fruit Moth on Nursery Stock

M. H. BRUNSON, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The oriental fruit moth *Grapholitha molesta* (Busck), a pest of peach, plum, quince, apple, and other plants, is now known to occur throughout most of the United States. Before it had reached its present range, the official agencies of a number of uninfested western States placed restrictions on the movement of nursery stock into those States from infested areas. For entry it was required that the stock be given a prescribed treatment (fumigation with methyl bromide). This restriction was based on the assumption that the larvae could hibernate successfully on nursery stock and be transported on it to new areas in a living condition. This assumption was challenged, and a clear-cut answer could not be found in the literature on the subject. Studies on the points in question were therefore conducted in New Jersey and Maryland in 1944 and 1945. Stock of the most susceptible kinds of plants in several nurseries was examined for larvae in the twigs and fruit. The plants on which larvae were found were examined in the fall for hibernacula, or winter cocoons.

LARVAE IN TWIGS ON NURSERY STOCK.—During the latter part of August and in September of the years 1944 and 1945 nursery stock was examined in five nurseries in New Jersey and in three in Maryland, to determine the larval population in the twigs. Succulent twigs and larvae were found in greatest abundance in the New Jersey nurseries and were scarce in Maryland, chiefly because of dry weather early in August of both years. Without succulent twig growth or fruit, this pest does not thrive.

In New Jersey more than 10,000 peach trees, representing all the common varieties, were examined in 3 nurseries in 1944. The greatest number of larvae found was 14 per 1000 trees, and the average was 5 per 1000. In 1945, 10,466 trees were examined in 2 New Jersey nurseries, and a heavier infestation was found. The greatest number found was 227 per 1000 trees, in the latter part of August. A reexamination of some of the same trees a month later (September 25) showed about 100 larvae per 1000 trees.

In Maryland the infestations were much lighter because of the lack of succulent twigs. In 1944 only 11 larvae were found in 23,250 peach trees examined, and the most heavily infested Maryland nursery averaged only a little more than 1 larva per 1000 trees. In 1945 the Maryland infestation was less than one-fifth as great, only 9 larvae being found in 43,600 trees examined in 3 nurseries.

Nursery stock other than peach was examined in 4 nurseries in New Jersey and 3 in Maryland in 1944. In New Jersey 9 larvae were found in twigs on 126 trees of ornamental peach (3 varieties), only 1 larva on 683 ornamental quince plants (8 varieties), and 30 larvae on 1246 ornamental cherry trees (on 6 of 13 varieties). No larvae were found on twigs of 3273 ornamental crab apple trees (11 varieties) and none on 4639 apple trees (13 commercial varieties).

In Maryland, no larvae were found in 1944 in twigs of the following trees:

2000 cherry	(10 varieties)
1100 nectarine	(3 varieties)
7357 apricot	(7 varieties)
3928 plum	(4 varieties)
6550 apple	(22 varieties)
500 pear	(6 varieties)
2650 ornamental plum	(2 varieties)
2657 ornamental peach	
75 ornamental quince	

In 1945 several thousand plants belonging to the genera *Prunus*, *Malus*, and *Cydonia* were examined for twig-infesting larvae in three nurseries in New Jersey and three in Maryland. The only larva found was on a species of flowering almond in New Jersey. Succulent twig growth was relatively scarce on stock other than peach in both States that year.

LARVAE IN FRUIT ON NURSERY STOCK.—Since it was known that oriental fruit moth larvae can develop in fruit on trees growing in nurseries, a study was made to determine what fruit was favored. Fruit on various plants was collected in four New Jersey nurseries in September and October, and the insects in them were reared to maturity and identified. Forty-two oriental fruit moths were reared from 530 fruits collected from three varieties of ornamental crab apple in three nurseries, and 16 from 126 fruits collected from ornamental quince in three nurseries. No moths were reared from fruits collected from hawthorn, mountain-ash, snowball, chokecherry, and Christmasberry.

HIBERNATION ON NURSERY STOCK.—To ascertain whether oriental fruit moth larvae would form hibernacula on peach stock, 1100 full-grown larvae reared in the laboratory early in September 1944 were released on 250 peach trees at the rate of 1, 3, 5, and 10 larvae per tree. Five hibernacula were formed.

In September and October 1944, a thorough search was made for oriental fruit moth hibernacula on 1104 peach trees representing more than 33 varieties and on 808 trees and plants of 20 varieties of 5 plants other than peach, including 8 varieties of ornamental crab apple, 5 varieties of ornamental cherry, 5 varieties of ornamental quince, 1 variety of Christmasberry, and 1 of hawthorn. Not one hibernaculum was found, although larvae had been found in the twigs and adult moths had been reared from fruits collected from many of the plants examined.

Early in October 1945 careful examination of 387 trees in the heavily infested New Jersey peach block revealed the presence of six oriental fruit moth hibernacula, and 86 summer cocoons. All hibernacula and summer cocoons were located on the base of the tree, at or within 1 inch of the ground level. These data show that oriental fruit moth larvae form hibernacula on peach nursery stock naturally, but that the proportion doing so is small.

SURVIVAL OF HIBERNATING LARVAE IN A FROST-PROOF STORAGE CHAMBER.—Many nurserymen remove stock from the field in the fall and store it over winter in frost-proof storage chambers. The stock is closely packed in the chamber and sold during the winter and spring. It was therefore of interest to determine whether hibernating larvae could survive on stock in such storage and, if so, when the moths emerged.

Mature oriental fruit moth larvae were induced to form hibernacula on 80 peach nursery trees (8 lots of 10 each) for commercial handling and exposure in a frost-proof storage chamber in a New Jersey nursery. The different lots, bearing from 1 to 11 hibernacula per tree, were stacked in the frost-proof chamber on November 28, 1944, along with 350 additional trees. The stack measured 4 by 4 by 6 feet and was made on 6 inches of salt-marsh hay with the tops of the trees in and the roots out. The roots were covered with shingletoe and sphagnum moss. The lots of trees bearing the hibernacula were well distributed in the stack, which was surrounded on all sides and above by other nursery stock. The stack was made by an experienced packer and received the same treatment as the other stock in the chamber. On March 20, 1945, the test trees were removed from storage and held in a laboratory chamber at 80° F., to accelerate moth emergence. Thirty-eight moths, or 9 per cent, emerged from the 418 hibernacula on the 80 trees.

To supplement these tests, peach twigs were infested with hibernating larvae from the same source used for infesting the nursery stock and were placed in different situations in the frost-proof storage. They were left in the storage chamber for the same period as the nursery stock, unless otherwise noted, and upon removal were handled in the same way. In one test 3 bundles of infested peach twigs, each 2 inches in diameter and 4 inches long, were enclosed in ventilated galvanized tins and placed in the experimental stack of peach trees. One hundred and seventy-two moths, or 63 per cent, emerged from the 273 hibernacula on the twigs.

In another test three bundles of in-

fested peach twigs, each 2 inches in diameter by 7 inches long, were enclosed in screen-wire cylinders and were then placed in the frost-proof storage chamber, one on top of the experimental stack of peach trees and two suspended over it, one 6 feet above the floor, and one 12 feet above it. One hundred and three moths, or 70 per cent, emerged from the 148 hibernacula on the twigs in the cylinder on the stack.

The 2 bundles of peach twigs bearing hibernacula in screen-wire cylinders held above the stack of peach trees 6 feet and 12 feet from the floor were allowed to remain in the frost-proof chamber until moths emerged. On May 7, 20 moths were found in the two cages, these having emerged within the week prior to that date.

As a check on the survival of hibernating larvae in frost-proof storage and the subsequent emergence of moths from them, larvae were allowed to cocoon in cardboard strips and were then held in the laboratory at a constant temperature of 42° F. until removed on March 20, 1945, to a laboratory room maintained at 80° to accelerate moth emergence. Two hundred forty-eight moths emerged from 304 hibernacula, an emergence of 82 per cent. The weekly mean temperature and humidity as recorded by a hygrothermograph machine in the frost-proof storage chamber from January 1 to May 7 are given in table 1. The machine was located above the stack of peach stock 12 feet from the floor, and was checked each week for accuracy. There is no record for the week February 5–12 due to the failure of the machine.

The two screen-wire cylinders containing hibernacula on bundles of peach twigs that were allowed to remain in the frost-proof chamber after March 20 were moved on the date the first moths were found, May 7, to a chamber kept at 80° F. in the laboratory at Moorestown, N. J. A total of 196 moths, or 60 per cent, emerged from 325 hibernacula.

At the time moths began emerging in the screen-wire cylinders in the frost-proof chamber, practically all the nursery stock that had been stored therein had been removed for shipment. The date of the first moth emergence was probably earlier than would have been the case had temperatures been normal in this vicinity in March and April. The mean daily temperature for March 1945, at Moorestown, was 50.5° F. whereas the normal for the month is 39.8°. The mean daily temperature for April 1945, was 55.5°, whereas the normal for the month is 50.5°.

OVIPOSITION ON HEELED-IN NURSERY STOCK.—It is the practice of some nurserymen to stack or heel-in nursery stock outdoors prior to shipment. Since adult oriental fruit moths may be present during the period such stock is held, they may deposit eggs on it, and the insect may be transported in that way to uninfested localities. Observations were therefore made on the tendency of the insect to oviposit on peach nursery stock heeled-in outdoors between the time of moth emergence in the spring and May 1. Twenty trees of the variety Golden Jubilee were divided into 10 lots of two trees each. On April 14, 1945, seven lots were heeled-in between rows of trees of different ages in two peach orchards, and three lots were heeled-in about 100 yards from peach orchards, in fields planted to rye. Seven days later five of the lots and 14 days later the remaining five lots were removed from the field, cut into short pieces, and placed with small green apples to provide food for any larvae hatching from eggs placed on the stock. During the 14 days trees were in the field the average temperature at 6 p.m., the time moths usually become active in the field, was 59° F., and the highest temperature was 65°. Considerable numbers

Table 1.—Weekly records of temperature and relative humidity in a frost-proof storage chamber in which oriental fruit moth hibernacula were stored, 1944–45.

Date	Temperature (°F.)			Relative Humidity (Per Cent)		
	Mean	Mean Minimum	Mean Maximum	Mean	Mean Minimum	Mean Maximum
Jan. 1–9	41	39	42	94	93	96
9–15	39	38	40	94	93	96
15–22	40	39	40	94	93	95
22–30	38	37	39	94	93	96
30–Feb. 5	36	35	37	93	91	96
Feb. 12–19	40	38	41	88	88	88
19–26	39	38	40	90	90	90
26–Mar. 5	44	42	46	95	95	95
Mar. 5–12	45	43	47	94	93	95
12–19	54	50	59	85	77	94
19–26	56	52	61	85	74	96
26–Apr. 2	62	56	68	73	55	92
Apr. 2–9	56	50	61	80	67	93
9–16	63	57	69	76	58	93
16–23	54	50	58	75	62	87
23–30	55	50	60	80	68	92
30–May 7	53	49	58	79	64	93

of moths were caught in traps in orchards immediately before the nursery stock was placed in the field, and moths were caught in traps in both orchards in which the nursery stock was placed during the period it was in them. No moths, cocoons or larvae were reared from the nursery stock, a fact which indicated strongly that no oriental fruit moth eggs were placed on it.

VIABILITY OF EGGS OF VIRGIN MOTHS.—In view of the possibility that an individual female oriental fruit moth might emerge from a hibernaculum on shipments of nursery stock received in localities where this insect was not known to be established, observations were made on the viability of eggs deposited by virgin females. A total of 83 virgin females and 55 mated ones were placed either in battery jars or individually in jelly glasses, and fresh pear foliage was provided on which the moths could oviposit. The virgin females deposited a total of 361 eggs, or an average of 4.3 eggs each, and the mated females deposited a total of 5463 eggs, or an average of 99.3 eggs each. The pear foliage bearing the eggs was placed in a chamber kept at 80° F. None of the eggs deposited by the virgin females hatched, but those deposited by the mated females hatched normally, and the larvae developed to maturity on small green apples.

DISCUSSION.—Because of the lightness of the infestation in most of the nurseries in which the studies were carried on, the negative data recorded in this paper have little significance. The apparent absence of larvae in the twigs of certain trees in the nursery does not necessarily indicate that such attack by the oriental fruit moth never occurs. Observations of infestation in the twigs of most of the common fruit trees have been recorded in the literature, although twig infestation in apple is reported to be rare. The fruit of hawthorn and Christmasberry has been recorded as subject to infestation, and probably would be attacked if the insect were abundant. On the other hand, there seem to be no published records of infestation in the fruit of mountainash, snowball, and chokecherry.

The failure to find hibernacula on species of nursery plants other than peach, under conditions of light infestation, does not mean that hibernacula are never found on such plants. It may be assumed that a certain percentage of larvae infesting the twigs or fruit of a given plant will form their cocoons on it.

SUMMARY.—The danger of transporting the oriental fruit moth, *Grapholitha molesta* (Busck), into new localities on nursery stock was investigated in New Jersey and Maryland nurseries in 1944, and 1945.

Oriental fruit moth larvae were found feeding in twigs of peach, ornamental peach, ornamental almond, ornamental quince, and ornamental cherry stock. No larvae were found in twigs of commercial apple stock or in twigs of a number of ornamental crab apple trees. Larvae were found, however, in the fruit of ornamental crab apple and ornamental quince. No larvae were found in the fruits of several other ornamentals.

Hibernacula of oriental fruit moth were found occurring naturally on peach nursery stock. Moths were reared from hibernacula on peach stock stored over winter in a commercial frost-proof storage chamber. However, only a small proportion of the larvae that constructed hibernacula on the nursery stock survived commercial handling and emerged as moths the following spring. Moths began to emerge from hibernacula on twigs in a frost-proof chamber from April 30 to May 7, 1945.

Oriental fruit moth eggs were not deposited on peach nursery stock heeled-in from April 14 to 28, 1945, in infested peach orchards and nearby fields. Very few eggs were deposited by virgin females, and those deposited did not hatch.

The studies reported in this paper have shown that the oriental fruit moth infests the twigs and fruit of many kinds of nursery stock, that some of the larvae construct winter cocoons on the nursery trees, and that a small percentage of the larvae in these cocoons survive the digging and storing of the nursery stock and emerge as moths the following spring.

Complete evidence was obtained on peach nursery stock only. With other kinds of nursery stock the results on certain points were negative, but not sufficiently conclusive to rule out the possibility that some kinds of nursery stock other than peach may at times be the means of establishing the oriental fruit moth in new localities.—11-29-46.

Feeding Experiments with DDT-Treated Pea Vine Silage with Special Reference to Dairy Cows, Sheep, and Laboratory Animals[1,2]

H. F. Wilson, N. N. Allen, G. Bohstedt, J. Betheil, and H. A. Lardy[3]

Experimental evidence is now available to show that DDT is highly effective for control of the pea aphid on canning peas. Results indicate that DDT residues remain on the vines up to the time of harvest and aid in preventing reinfestation of treated fields. Since the majority of vines and pods remain after the plants have passed through the viner, we must raise the question of whether enough DDT remains on the vines after stacking ensiling, and storing to be a possible hazard to livestock fed on pea vine silage.

Even more important is the problem of whether meat and other animal products from livestock fed on silage containing even small amounts of DDT are a possible hazard to man. Previous investigations by Orr & Mott (1945), Woodward, *et al.* (1945), and Telford & Guthrie (1945) have demonstrated that DDT will accumulate in certain tissues and in milk fat of domestic and laboratory animals.

In an effort to determine the influence of feeding pea vines treated with DDT on dairy cattle and sheep, a series of feeding tests was made by staff members of the Wisconsin Agricultural Experiment Station beginning in November 1945 and continuing until April 1946.[4]

Experimental Plan and Types of Silage Used.—Two lots of pea vine silage were prepared for feeding tests: One lot at a farm near Arlington, and the second lot at a farm near Beaver Dam, Wisconsin.[5]

The vines used at the Arlington farm were of the Alaska variety and were brought directly from the viner to the silos. Twenty-five tons of vines were run into each of two concrete silos, one lot having DDT added at the rate of 1 pound per ton of vines. The DDT preparation was a 60 per cent *Pyrax* and 40 per cent DDT mix and was added to the chopped vines as they were taken up by the blower. This was done with a meat grinder calibrated to put out a certain amount of the DDT dust during each revolution of the handle. With every load of vines a definite weight of DDT dust was used. It was not possible to obtain a completely even rate of distribution per pound of vines. Therefore we can only assume that over a long feeding period an average amount of DDT per animal would be assured. The rate of application was assumed to be 0.227 grams of DDT per pound of green weight. When fed, beginning November 9, the amount was determined to be 0.049 grams of DDT per pound of silage. A sample of the silage taken from the bottom of the silo at the end of the experiment showed 653 ppm. on a moisture free basis. This is equivalent to 0.074 grams per pound of silage.

The vines used at the Beaver Dam farm were of the Prince of Wales type and were treated when 14 inches high with a 5 per cent DDT dust at the rate of 40 pounds per acre; an estimated 2 pounds of DDT was applied to 6 tons of vines. In the application of rotenone dusts we have estimated that not more than half of the dust is held on the vines so that at the most, these vines held not more than 1 pound of DDT per calculated 6 tons (by actual weight other similar fields produced approximately 7 tons of vines per acre).

If all the estimated amount remained on the vines at the time the vines were put in the stack, the amount would have been 0.038 grams per pound of silage. (In 1946 an analysis of vines just after treating with a 5 per cent dust showed 6 parts per million of DDT. This is equal to 0.0027 grams of DDT per pound. When these vines were analyzed after passing through the viner they showed only 3 parts per million which is equivalent to .00135 grams per pound of green silage.)

[1] Contribution from Wisconsin Agr. Expt. Sta. Authorized for publication by the Director.

[2] Early publication secured by payment of printing costs.

[3] Professor of Economic Entomology, Professor of Dairy Husbandry, Professor of Animal Husbandry, Graduate Assistant in Biochemistry, and Asst. Professor in Biochemistry respectively.

[4] The writers acknowledge the aid received from the Oconomowoc Canning Co. of Poynette, Wisconsin, the Central Wisconsin Canneries of Beaver Dam, Wisconsin, and the Wisconsin Canners Association.

[5] Tests carried on at the Sloan Farm near Arlington, and Warren Clark Farm at Beaver Dam, Wisconsin.

When the Beaver Dam silage was analyzed for DDT in December 1945, less than 1 ppm. was found.

PROCEDURE IN THE FEEDING TESTS.—Ten cows and 50 sheep were used in the tests at the Arlington farm, and two Holstein cows were fed on DDT treated silage at the Beaver Dam farm. A single cow in the University herd was fed 24 grams of DDT per day with her grain.

Rat assays were run by the Biochemistry Department on the milk from DDT-fed cows at the Arlington farm and the single cow at the University dairy barn.

On the Arlington farm the 10 cows were divided into two lots, each consisting of one Guernsey and four Holstein cows weighing from 1000 to 1400 pounds. Pea vine silage was fed at the rate of 30 to 40 pounds per cow per day which was approximately 3 per cent of each cow's live weight. Lot 1 received the DDT-treated silage and lot 2 the untreated silage held in a second concrete silo. Both lots received clover hay of fair quality and a concentrate mixture containing approximately 16 per cent protein. The cows were weighed at about 2:30 P.M. on one day of each second week.

Milk for the rat feeding trials was obtained twice weekly from the pooled production of each lot. Individual milk samples were taken monthly for fat determination, and composite samples were taken from each lot occasionally for DDT analysis. The feeding started November 9 and continued for some cows until April.

The sheep feeding trials consisted of 30 western lambs fed 3 pounds of silage daily and 20 pregnant and nursing ewes fed 6 pounds daily. Each group was divided into two lots as nearly equal in weight as possible. Lot 1 of each group received the DDT treated silage and lot 2 the untreated silage.

RESULTS FROM DDT-FED COWS.—Table 1 shows the amount of silage fed and the estimated maximum DDT intake of each cow in lot 1 at the Arlington farm. Because of a shortage of silage, cows 210, 213, and 341 were fed for only 118 days. Cow No. 551 was slaughtered after 127 days of feeding to get body parts for DDT analysis. Cow No. 288 was continued on DDT silage for 141 days to maintain a supply of milk for the calves.

No differences were observed in the general welfare or behavior of individuals in the two lots. Since the cows were in various stages of lactation, no attempt was made to measure differences in milk production. No evidence appeared to indicate that the DDT had any effect on milk production

Cow No. 288 in lot 1 dropped a strong female calf after 67 days of feeding on treated silage. This calf was fed milk from lot 1 cows for 75 days, and when the experiment closed, was in excellent health and condition. Cow No. 210 dropped a strong male calf after 102 days on treated silage. This calf also fed on milk from the No. 1 lot was in excellent condition when slaughtered after 33 days.

Cow No. 287 in the control group dropped a calf at the end of 109 days which after the third day was fed on milk from lot 1. All the calves were very strong and thrifty throughout the experiment. No lesions or other characteristic signs of DDT poisoning were observed in the internal organs of the animals slaughtered. The results of analysis of body tissues and milk from these animals are given in table 1A.

Table 1—Silage and estimated DDT intake of dairy cows.

Cow No.	Breed	Silage: Days Fed	Silage: Pounds Fed	Av. Live Weight	Total DDT gms.	Daily Intake[1] per 1000 lbs. gms.
Lot 1—Treated Silage						
551	G	127	4335	1019	212	1.64
213	H	118	4939	1302	242	1.58
210	H	118	4705	1313	230	1.48
341	H	118	4054	1020	198	1.64
288	H	141	5595	1171	274	1.66
Lot 2—Untreated Silage						
547	G	141	4732	1034	—	—
128	H	74	2595	1432	—	—
260	H	141	4574	1106	—	—
298	H	141	4982	1181	—	—
287	H	141	5590	1369	—	—

[1] Estimated maximum DDT intake based on analysis of silage as fed.

A.—Tissue analyses from dairy cows.

Animal No.	Muscle Tissue ppm	Liver ppm	Body Fat ppm	Milk ppm
551	3.8	6.1	221.0	
210 calf	3.1	6.2	305.0	
Group 1	Mixed milk			15

B.—Analyses of tissues and milk from cow 711.

Fat removed by biotomy (4/24/46)	380 ppm
Milk	44 ppm
Milk 3/26/46 (Feeding discontinued 3/19/46)	15 ppm
Milk 4/19/46	7 ppm
Petroleum ether extract of surface material on skin	115 ppm[1]

[1] Only 0.4 gm. material available for analysis.

The quantitative determination of DDT was done by the method of Schecter *et al.* (1945) with the following modification.[6] The ether extract of the samples was evaporated to dryness, taken up in dry chloroform and thoroughly extracted with mixtures of concentrated sulfuric acid, fuming sulfuric acid and sodium sulfate to remove extraneous fatty material and oxygen-containing compounds. The samples were then worked up according to the published procedure. The color was read with an *Evelyn* photoelectric colorimeter using a filter having maximum transmission at 580 m.u.

Blood samples were collected at 2- to 3-week intervals throughout the experiments and analyzed for carotene, vitamin A, vitamin C, calcium, and hemoglobin. Bilirubins, very low at the beginning, were not determined later. No changes from the normal level of these constituents were observed and no differences between the groups were detected.

RESULTS ON DIRECT FEEDING OF HEAVY CONCENTRATIONS OF DDT (Cow 711).—The data from this test should prove conclusively that there is little possibility of ill effect in feeding plants treated with concentrations of DDT necessary for commercial insect control to dairy cows. This cow fed 24 grams of DDT daily for a period of 5 months showed no outward signs of ill effect from the DDT. A high concentration of DDT was found in the milk and body fat and in a fatty secretion swabbed from the skin surface with petroleum ether (Table 1, B). It was interesting to note that the daily dose of 24 grams per day during the first half of the gestation period did not interfere with the birth of a healthy normal calf 4.5 months after the feeding was discontinued.

RESULTS WITH COWS FED ON SILAGE FROM PEA VINES TREATED WITH 5 PER CENT DDT DUST AT 40 POUNDS PER ACRE.—Two large Holstein cows were fed on DDT silage from November 12, 1945 until late in March, 1946. The schedule of feeding was as follows:

Nov. 12–Nov. 16—20 lbs. of silage twice daily
Nov. 17–Nov. 25—25 lbs. of silage twice daily
Nov. 26–Dec. 1—30 lbs. of silage twice daily
Dec. 2–Dec. 11—35 lbs. of silage twice daily
Dec. 12–Apr. 1—40 lbs. of silage twice daily

[6] Personal communication from Dr. H. L. Haller.

Six pounds of ground feed containing corn, grain, soybean meal, and alfalfa were fed twice daily with the silage. No indication of ill effects from DDT could be observed on either cow or on a calf born of one of them. Less than one part per million of DDT was detected in the silage and none in the milk.

FEEDING TESTS WITH SHEEP AT THE ARLINGTON FARM.—The ewes used in this test were grade Shropshire and Hampshire stock, averaging 136 pounds. They were fed clover hay and pea vine silage from November 14 to February 8, about 4 weeks before lambing. From February 8 until March 8 they were continued on hay and pea vine silage, but in addition were given 1-half pound daily of equal parts corn and oats. This ration was increased to 2 pounds per day after lambing.

No significant differences could be observed between the lambs born to ewes in the DDT group and three of the control group. The lambs were vigorous at birth and continued in excellent health. The birth weights were 8.1 pounds per lamb in the DDT group where 9 ewes gave birth to 5 pairs of twins and 4 singles totalling 14 lambs. The birth weights of the lambs in the check group averaged 9.2 pounds, 8 ewes giving birth to 2 pairs of twins and 6 singles totalling 10 lambs.

The average weight of fleeces was 8.76 pounds for both lots of ewes. The average daily gain for both lots during 62 days of wintering was 0.24 pounds per day.

The western lambs averaged 81 pounds in weight on November 29, 1945, when they were started on the feeding tests. The control group made an average daily gain of 0.31 pounds and the DDT silage group an average daily gain of 0.27 pounds. This difference is not considered significant. The silage and estimated intake of DDT is shown in table 2.

None of the ewes or lambs fed in these trials showed any physical evidence of ill effect from the DDT. The appearance, evidence of physical vigor, appetite, rate of gain and maintenance of body weight was completely normal.

On January 15, A. C. Kelman of the Veterinary Science Department of the University took temperatures of both the western lambs and the ewes. He again took temperatures of the ewes May 8,

the end of the DDT feeding period, the western lambs having been slaughtered on March 3. No significant differences between the DDT silage fed animals and the controls were observed. Dr. Kelman stated that on the basis of his observations and tests, the animals receiving DDT were healthy. Six ewes, four western lambs, and three spring lambs were slaughtered and some of the animal tissues analyzed for DDT (Table 2). No lesions or other signs of DDT poisoning were observed in the internal organs of the slaughtered animals.

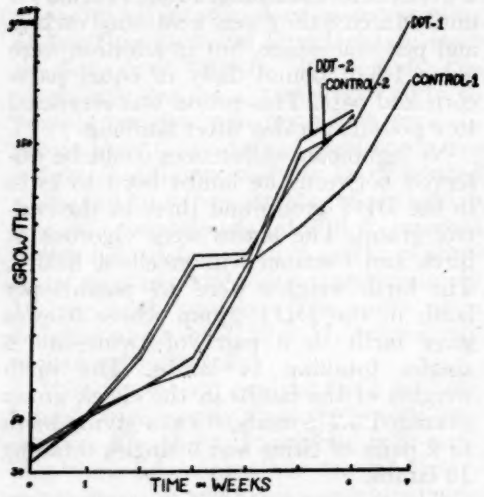

FIG. 1.—Growth curves of Sprague-Dawley rats whose sole dietary constituent was mineralized milk from the Sloan herds are plotted. DDT-1 refers to the first group on milk from the DDT herd. Control-1 group was fed on milk containing no DDT. DDT-2 and Control-2 refer to the groups in the second experiment.

RAT FEEDING TESTS.—The nutritive value and possible toxicity of the milk from cows ingesting DDT was determined by feeding the milk, plus certain minerals, to growing albino rats as the sole constituent of their diet. It is well known that, when fortified with iron (1 mg/100 ml.), copper (.1 mg./100 ml.) and manganese (.1 mg./100 cc.), cows' milk supports a good rate of growth in rats, and Evans & Phillips (1939) have shown such a diet to be adequate for reproduction through four generations.

With each experimental lot of 8 rats (4 males, 4 females) receiving mineralized milk from cows receiving DDT in their ration, a control lot of 8 rats was kept on milk from control cows.

Two series of tests were run with white weanling rats. In the first test milk from the cow fed 24 grams of DDT per day was fed to a group of 8 rats, 4 male and 4 female. A control was run with a similar

Table 2.—Silage and DDT intake of ewes and lambs.

(Feeding of DDT rations to ewes discontinued May 8. Western lambs killed March 3, 1946.)

	Daily Ration Silage	Estimated DDT Content	Estimated ppm
	lbs.	*grams*	
Ewes	6	0.270	106
Western lambs	3	0.135	62

A.—Analysis of sheep tissues

Ewes	Slaughtered		Muscle ppm	Fat ppm
No. 150	May	9	1	37
267	May	9	1	145
266	June	12	1	48
269 (control)	May	9	1	8[1]
279 (control)	May	9	0	0
265	Aug.	16	1	18
Suckling lamb	May	9	1	43
Suckling lamb	June	12	1	10
Suckling lamb	Aug.	16	—	9
Western lambs				
715 (control)	March	3	1	1
717 (control)	March	3	1	12[1]
720	March	3	5	96
724	March	3	4.4	

[1] Though an absorption in the photometer was obtained corresponding to the value shown, no blue color was noticed in the solution and the absorption was probably not due to DDT.

Table 3.—Summary of analytical data on blood constituents.

Blood Constituent	November 8, 1945				February 25, 1946			
	Experimental		Control		Experimental		Control	
	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.
Hemoglobin gm/100 cc	10.5 –12.0	11.2	10.4 –12.7	11.2	10.0 –12.5	11.6	11.1 –12.2	11.6
Serum calcium mg per cent	8.9 –12.0	10.2	10.8 –11.9	11.1	10.7 –12.3	11.7	10.7 –12.5	11.6
Vitamin A v/cc plasma	0.33– 1.0	0.51	0.20– 0.47	0.32	0.15–0.52	0.33	0.22– 0.40	0.32
Ascorbic acid mg/100 cc plasma	0.35– 0.58	0.48	0.39– 0.67	0.49	0.42–0.66	0.58	0.17– 0.46	0.29[1]

[1] Determinations on 3 cows only.

group of rats using milk from cows in the same barn on the same feed, except for DDT.

Milk from the cow fed 24 grams of DDT per day, was found by analysis to contain 44 ppm. of DDT. After 1 week the effect of DDT in the milk was evident; after 4 weeks the average weight of the control group was more than 50 grams above that of the DDT milk group. To see if this effect was reversible, four rats on the DDT regimen were put on control milk and four from the control group were put on DDT milk. From the growth curves it could be seen that the effect was reversed in a week after removal of DDT from the diet. The older rats (7 weeks old) required a longer period of DDT feeding before they began to show signs of decreased rate of growth. The only symptoms observed were anorexia. No gross pathology was observed after autopsy at the end of 7 weeks. A similar test was run with milk from the Arlington herd, using the same procedure, except that the DDT and control groups contained but six rats each. The results are shown in figure 1. This experiment was repeated, since in the first run the rats on DDT fared better than those on the control. In the second run there were no significant differences between groups. Analysis of the milk used in this series of tests at different times showed DDT to be present in from 1 to 15 ppm.

SUMMARY.—Dairy cows and sheep showed no observable ill effects from being fed for 4 to 5 months on pea vine silage treated with 1 pound of DDT per ton of fresh vines when put in a silo. Suckling calves and lambs also showed no ill effects although 15 ppm. of DDT was found to be present in the cows' milk. Laboratory analyses showed that DDT accumulated in the muscle tissues, liver, and body fat of both cows and calves. Accumulations in the body fat and milk were appreciable.

Cows fed for a similar period on pea vine silage from a field treated with DDT,

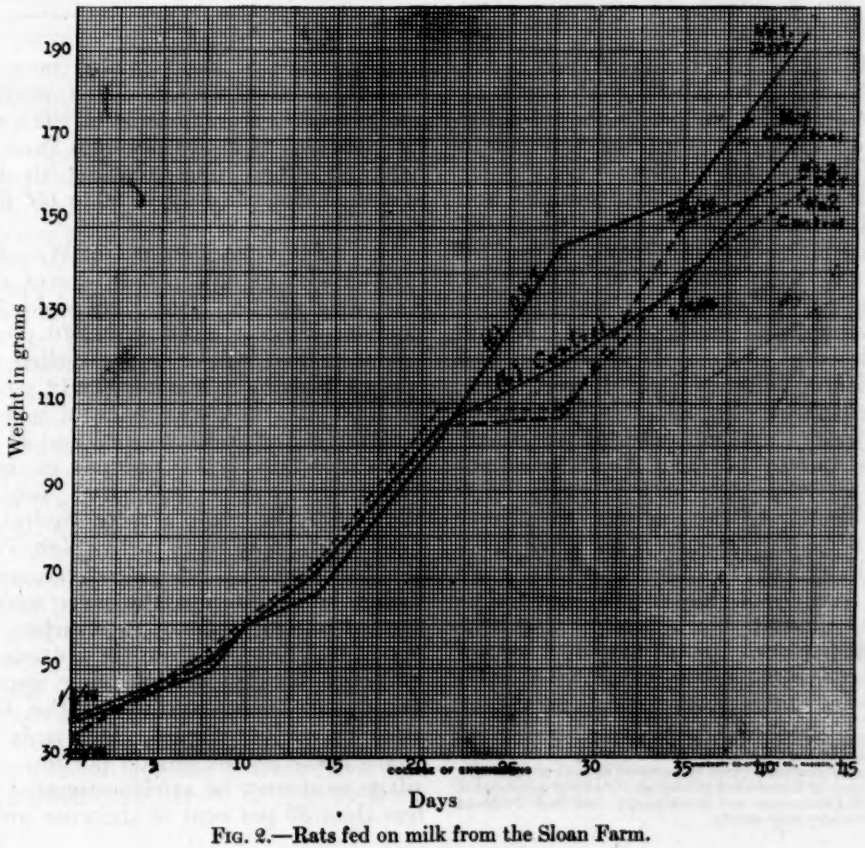

FIG. 2.—Rats fed on milk from the Sloan Farm.

2 pounds per acre in a 5 per cent dust, showed no ill effects. Less than one part per million of DDT was found in the silage in this test and none in the milk.

A cow fed 24 grams of DDT daily in grain for 5 months did not show any ill effects, but a high increase of DDT was found in the body fat and milk.

Sheep fed in the trials did not exhibit physical evidence of ill effects from the DDT although 1 part per million of DDT was found in the muscle tissue and up to 145 parts per million in the body fat. Suckling of ewes fed on DDT silage showed up to 1 part per million of DDT in the muscle and 43 parts in the body fat.

Laboratory rats fed milk containing 44 ppm. of DDT showed distinct toxic effects but those fed milk containing only 15 ppm. showed no toxic effects.—12-13-46.

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DDT Residues on Pea Vines and Canned Peas from Fields Treated with DDT Dusts[1,2]

H. F. WILSON, A. S. SRIVASTAVA, W. B. HULL, J. BETHEIL, and H. A. LARDY[3]

In 1946 the DDT residue studies begun in 1945 were continued by determining the residues left on pea vines from the time of treatment until harvest and in stacked silage and in canned peas. Some data is included from 1945 samples and from two samples of vines from Belvidere, Illinois, and one sample each of canned peas and fresh silage from Blytheville, Arkansas. The main data was obtained from samples of vines and peas taken in experimental plots at Beaver Dam and Waunakee, Wisconsin. At Beaver Dam, treatments were applied at 40 pounds per acre with a *Niagara Dri-fog* 18 nozzle duster and by airplane. Dusts were applied at Waunakee with a ground machine similar to the one used at Beaver Dam at 35 and 50 pounds per acre. Dusts containing from 1 to 5 per cent DDT were used. Samples of vines from selected plots were collected immediately after the treatments were applied and then several times previous to harvest. At harvest time samples of hand shelled peas and peas at the viner were collected, weighed, and placed in storage at 4° C. until time for analysis. Samples of vines from the field and after vining were first air dried and then dried further at 50 or 60° C for analysis.

When the vines were cut at Waunakee for the silage stack, a half-acre of vines was weighed and found to yield 7185 pounds, or on a basis of 14,370 pounds per acre. The weight of the shelled peas was 2458 pounds, leaving 11,912 pounds of vines. A study was made of vines to determine the relative portion of the vine on which DDT residues might be found. In the experimental field at Waunakee the vines were treated at the blossom stage 12 to 14 inches high. When the field was cut the vines averaged 24 inches in height and the pods were all formed on the upper 6 to 8 inches. The leaves had dropped from the bottom 6 to 8 inches of the stem leaving approximately 10 inches on which the DDT residues might remain. The pods and stems make up the greater portion of the silage so it may be safely estimated that less than 50 per cent of the vine growth

[1] Contribution from Wis. Agr. Expt. Station. Authorized for publication by the Director.

[2] Early publication secured by payment of costs of printing.

[3] Professor of Economic Entomology, Graduate assistants in Economic Entomology and Biochemistry, and Asst. Professor of Biochemistry respectively.

had been exposed to DDT. At Beaver Dam the vines of the larger vine type (Prince of Wales) averaged 42 inches in length and the first pod was formed 24 inches from the tip so the DDT was restricted to the lower 18 inches of vine growth. Here again the leaves had dropped from the lower 8 to 10 inches of the stem and not more than 10 inches of the vine growth could have contained any DDT residues. In this case much less than 50 per cent of the vine growth could have carried any DDT. Only a relatively small amount of this actually clings to the vines as shown by the amount found on the vines immediately after the dust was applied. Where the application was 35, 40, and 50 pounds of 5 per cent dust per acre, the DDT recovered was 3.6, 6 and 9 to 13 parts per million. When the vines came through the viner, only 3 ppm. were found on the vines treated with the 35 pound per acre application.

Table 1.—DDT dusts applied to canning peas in 1946 and rate of application.

LOCATION	PER CENT DDT	PER CENT SOLVENT	PER CENT ROTENONE	LBS. P. A.
Beaver Dam	1	3[1]	0.5	40
Beaver Dam	2	3[1]	0.25	40
Beaver Dam	2.5	2[2]	—	40
Beaver Dam	3	2[2]	—	40
Beaver Dam	5	—	—	40
Waunakee	3	3[1]	—	35
Waunakee	5	—	—	35–50
Waunakee (J. E. Dudley)	5	2[3]	—	
Blytheville, Ark.	2	2[4]	0.5	40
Belvidere, Ill.	2	[5]	0.25	35

[1] One-half propylene laurate and one-half SAE10 lubricating oil.
[2] *Yarmor* pine oil.
[3] Technical DDT dissolved in carbon tetrachloride.
[4] *Lethane* 60.
[5] Commercial dust (*Agicide*).

The types of dust used and rate of application are shown in table 1.

In all 87 samples were taken of which six were taken by J. E. Dudley from his experimental plots. A selected group of 34 have so far been analyzed. O. W. Alexander, of the research department of the American Can Company, collected 13 samples of vines and peas which were analyzed in the American Can Company laboratory. The results from these samples are shown in table 7. Data from five samples taken by Mr. J. E. Dudley from his experimental plots for pea aphid control are included in the tables. The modified[1] colorimetric method of Schecter & Haller[2] was used for the DDT determinations. Source of samples, rate of DDT application, and amounts of DDT recovered are shown in Tables 2 to 6.

Table 2.—Samples of vines taken immediately and at later dates after treatment had been made with a ground machine.

SOURCE OF SAMPLE	POUNDS PER ACRE OF APPLICATION	PER CENT DDT	DATE OF TREATMENT	DATE OF SAMPLE	DDT FOUND ppm
Beaver Dam	40	1	June 13	June 13	3
Beaver Dam	40	2	June 13	June 13	2
Beaver Dam	40	2.5	June 13	June 13	5
Beaver Dam	40	3	June 13	June 13	5
Beaver Dam	40	5	June 13	June 13	6
Beaver Dam	40	5	June 13	June 26	3
Beaver Dam	40	Control	June 13	June 11	0
Beaver Dam	40	5	June 13	July 6	4
Waunakee #1 planting	35	5	June 22	June 29	2
vines from 1st planting	35	5	June 22	July 6	3
Waunakee 2nd planting	50	5	June 22	June 22	9–13
	35	5	June 22	July 5	3
Waunakee (J. E. Dudley)	35	5	June 11	July 5–8	3

SUMMARY.—*DDT found on pea vines.* DDT residues were found on pea vines treated with dusts containing from 1 to 5 per cent DDT at 40 pounds per acre When these dusts were applied on the experimental plots at Beaver Dam, Wisconsin with a ground machine, the residues ran from 2 to 6 ppm. at the time of application on June 13. On June 26 one sample from a 5 per cent plot showed 3 ppm. and another sample taken July 6 showed 4 ppm.

Table 3.—Samples of vines taken immediately and at later dates after treatments had been applied by airplanes.

SOURCE OF SAMPLE	POUNDS PER ACRE	PER CENT DDT	DATE OF TREATMENT	DATE OF SAMPLE	DDT FOUND ppm
Belvidere	35	2	June 1	June 1	None
Belvidere	35	2	June 1	June 1	None
Beaver Dam	40	2	June 23	June 25	2
Beaver Dam	40	5	June 23	June 25	3
Beaver Dam	40	5	June 23	June 29	2
Beaver Dam	40	5	June 23	June 25	3
Beaver Dam	35	3	June 23	July 6	3.1

Dusts containing 3 and 5 per cent DDT applied by airplane at 35 pounds per acre gave residues of 2 and 3 ppm. No DDT was found in samples of vines treated at

[1] Wilson, H. F. *et al.* (Page 801.)
[2] Schecter, M. S., Soloway, S. B., Hayes, R. A., and Haller, H. L. Colorimetric Determination of DDT. Ind. Eng. Chem. 17, pp. 704–709. 1945.

Table 4.—Per cent control of the pea aphid obtained using variable concentrations of DDT and benzene hexachloride alone and conditioned with oil solvents and in combination with rotenone.

No.	Materials[5] Per Cent Rotenone	DDT	BHC[6]	Oil Solvent	Replicate No.	June 16 & 17 Aphids per Sweep	June 16 & 17 Per cent Control	June 23 Aphids per Sweep	June 23 Per cent Control	June 26 Aphids per Sweep	June 26 Per cent Control
1	0.75			2[1]	8	60	89	56	90	85	75
2[4]	0.25				8	92	83	142	74	97	73
3	0.5	1.0		3[1]	8	45	92	19	97	30	92
4	0.25	2.0		3[1]	8	42	92	26	95	20	94
5		2.5		2[2]	8	54	90	34	92	38	89
6		2.5		2[3]	8	44	92	20	96	46	87
7		3.0		3[1]	8	52	91	21	96	46	87
8		3.0		3[1]	8	46	92	—	—	28	92
9	0.25		2	3[1]	8	65	88	53	90	98	72
10			5	2[2]	8	52	91	45	91	56	84
11			5	2[3]	8	84	85	70	86	117	67
12[4]	0.25	2.0			4	43	92	29	95	—	—
13		5.0			4	69	88	24	96	—	—
Checks						550		550		350	

Average number of aphids per sweep required for significant difference, June 16 and 17, was 17.
[1] One-half propylene laurate and one-half SAE10 lubricating oil.
[2] *Yarmor* pine oil.
[3] *D.H.S.* activator.
[4] Commercial preparation—*Agicide*.
[5] *Pyrax* was the dispersant in all cases.
[6] Benzene hexachloride.

Belvidere, Illinois, with a dust containing 2 per cent DDT and 0.25 per cent rotenone.

At Waunakee, Wisconsin, dusts containing 3 and 5 per cent DDT were put on with a ground machine at 35 pounds per acre for the 3 per cent dust and at 35 and 50 pounds for the 5 per cent dust Samples of vines treated with 3 per cent DDT have not yet been analyzed.

One sample of vines treated with a 5 per cent DDT dust at 35 pounds per acre June 22 showed 2 ppm. June 29. Two other samples collected July 5 and 6 showed 3 ppm.

A sample of vines treated with 50 pounds per acre of 5 per cent DDT dust on June 22 and collected immediately after treatment showed 9 to 13 ppm. A sample of silage from this area taken from the stack October 10 showed only 5 ppm.

Shelled and canned peas. No DDT was found in any sample of peas shelled by hand or in the viner.

Silage. A sample of silage known to contain 454 grams of DDT per ton of vines placed in a silo in June 1945 showed only 98.3 grams per ton of silage in December. No DDT was found in silage samples taken in from a stack of silage made from vines treated with 40 pounds per acre of a 5 per cent DDT dust at Beaver Dam in June 1945. No DDT was found in a fresh sample of silage sent in from Blytheville, Arkansas.

At Waunakee, 3.6 ppm. were found in

Table 5.—Samples of peas shelled by hand in the field at time of cutting and canned peas.

Source of Sample	Pounds per Acre	Per Cent DDT	DDT—ppm
Shelled peas			
Beaver Dam	40	5	0
Beaver Dam	40	5	0
Waunakee from viner	35	5	0
Waunakee from viner	35	5	0
Waunakee shelled peas	35	5	0
Pods less peas (J. E. Dudley)	35	5	0
Shelled peas (J. E. Dudley)	35	5	0
Peas at viner (J. E. Dudley)	35	5	0
Canned Peas			
Beaver Dam—airplane (U.S.D.A.)	40	3	0
Beaver Dam—airplane (U.S.D.A.)	40	5	0
Beaver Dam—airplane	40	3	0
Beaver Dam—airplane	40	5	0
Beaver Dam—airplane	Control	0	0
Waunakee—ground machine	35	3	0
Waunakee—ground machine	35	5	0
Waunakee—ground machine	50	5	0
Waunakee—ground machine (U.S.D.A.)	35	3	0
Waunakee—ground machine (U.S.D.A.)	35	3	0
Waunakee—ground machine (U.S.D.A.)	35	5	0
Waunakee—ground machine (U.S.D.A.)	35	5	0
Blytheville, Ark.	40	2	0

(U.S.D.A.) samples analyzed at Insecticide Investigation Laboratory, Bureau of Entomology and Plant Quarantine.

Table 6.—Samples of pea vine silage taken immediately after and at various times after stacking.

SOURCE OF SAMPLE	POUNDS PER ACRE	PER CENT DDT IN DUST	DDT ppm
1945 treated vines			
Beaver Dam, Feb. 1946 (U.S.D.A.)	40	5	0.2 organic chlorine
Beaver Dam, Feb. 1946 (U.S.D.A.)	(untreated silage)	—	0.2 organic chlorine
Arlington, Feb. 1946 (U.S.D.A.)	(1# per ton of vines)	—	98.3 organic chlorine
Arlington, Feb. 1946 (U.S.D.A.)	(untreated silage)	—	2.23 organic chlorine
Beaver Dam, Dec. 1946	40	5	1.0
1946 treated vines			
Waunakee—newly made stack July 9.	35	5	3.6
Blytheville, Ark.	40(?)	2	0
Waunakee, Sept. 5—analyzed Nov. 10 (top of stack)	50	5	5–7
Waunakee, Oct. 10—analyzed Nov. 10 (inside stack)	50	5	5.0

(U.S.D.A.) These samples were collected in February 1946 and forwarded to the Division of Insecticides laboratory of the Bureau of Entomology and Plant Quarantine. The results are based on determined organic chloride. The two samples from Beaver Dam were taken from silage stacks and the two from Arlington from silage placed in silos for the feeding tests.

fresh silage going into the stack from vines treated with a 5 per cent dust applied at 35 pounds per acre. Silage collected September 5 from the top of the stack of vines treated with 5 per cent DDT dust from the area treated with 50 pounds per acre showed 5 to 7 ppm. A sample of silage taken from within the stack on October 10 showed only 5 ppm. A sample of silage from vines collected November 10 from the same source showed 4 ppm. of DDT.

Table 7.—Samples collected at Waunakee on July 7, 1946 by O. W. Alexander of the American Can Company.

DESCRIPTION OF SAMPLES	DDT FOUND[1]
	ppm
Vines cut from 3% DDT plot	2.0
Vined peas cut from 3% DDT plot	0.1
Washed peas cut from 3% DDT plot	0.1
Blanched peas cut from 3% DDT plot	0.1
Processed peas cut from 3% DDT plot	0.1
Processed peas cut from 3% DDT plot	0.1
Vines cut from 5% DDT plot	2.0
Vines cut from 5% DDT plot	1.3
Vined peas cut from 5% DDT plot	0.1
Washed peas cut from 5% DDT plot	0.1
Blanched peas cut from 5% DDT plot	0.1
Processed peas cut from 5% DDT plot	0.1
Processed peas cut from 5% DDT plot	0.1

[1] Vines and canned peas from untreated peas analyzed at the Wisconsin Experiment Station showed color equivalent to 0.2 ppm of DDT. This shows that when not more than 0.2 ppm are indicated that there is no DDT present.

These samples were taken from a planting of Perfection peas treated with 3 and 5 per cent DDT dusts applied at 35 pounds per acre, June 22, during the first blossom stage. Samples were taken from freshly cut vines and peas from the viner. Mr. Alexander then followed commercial runs through the factory taking samples after washing and before blanching, after blanching and finally samples of processed peas. The samples were stored at approximately 0° F. between collection and analysis.

CONCLUSIONS.—Experimental results show that a high degree of control of the pea aphid can be obtained with 3 to 5 per cent DDT combined in a powdered insecticide.

Based on the data given in this paper, a 3 per cent DDT dust at 35 to 40 pounds per acre, or a 5 per cent DDT dust at 30 to 35 pounds per acre can be recommended for pea aphid control. For those who desire a greater measure of safety, we recommend a dust containing 2 per cent DDT and 0.25 per cent rotenone. This dust was found to be as effective as any used in 1946. Where crop by-products are used for animal feeding, consideration must be given to possible residues of DDT remaining on or in such materials at the time of their utilization.

SCIENTIFIC NOTES

Repellent Properties of Extract of *Amorpha fruticosa*[1]

CHARLES H. BRETT, *Oklahoma Agricultural Experiment Station, Stillwater*

An acetone extract from the fruit of the indigobush, *Amorpha fruticosa* L., has been reported (Brett 1946) repellent for 12 or more hours to chinch bugs, grasshoppers, blister beetles, tent caterpillars, ailanthus caterpillars, dog fleas, horn flies, and house flies.

McCrory (1944) found cabbage worms refused to remain on cabbage plants sprayed with acetone extract but the moths laid eggs as readily on treated plants as on untreated ones. Larvae hatching from these eggs devoured the treated plants completely with no harmful effects.

A continued study of repellent properties of *Amorpha* extract is reported in this paper.

METHODS AND RESULTS.—Chinch bug, *Blissus leucopterus* (Say). Both nymphs and adults were encircled by barriers of standardized *Amorpha* dust, 1 inch wide. About 500 insects were placed in the center of each of four such barriers. Less than 33 per cent of the bugs had crossed the barriers at the end of 10 hours. Repellency was nil at the end of 24 hours. Twenty per cent of the bugs which crossed were dead at the end of 24 hours as compared with 15 per cent in the checks.

Comparative tests using 5 per cent DDT dust in the barriers killed 16 per cent of the bugs by the end of 24 hours. Nearly all insects had crossed this dust at the end of 15 minutes. Four per cent DN dust killed over 90 per cent of the bugs by the end of 6 hours. No repellency was shown. Ten per cent sabadilla dust killed all of the bugs within an hour. Sabadilla was not repellent but affected the bugs so quickly that 30 per cent died without being able to cross the barriers.

Striped cucumber beetle DIABROTICA VITTATA (Fab.). Laboratory tests showed *Amorpha* extract to be very repellent to this insect for more than 12 hours. Infested garden plants dusted with *Amorpha* were freed of beetles. Dead insects were not present and subsequent laboratory tests showed this dust to have little toxic effect.

Mosquitoes, AËDES AEGYPTI (Linn.) and A. ALBOPICTUS (Skuse). *Amorpha* showed very little repellency against these species in time-till-first-bite tests. Bites were received from caged hungry mosquitoes at the end of 1 to 27 minutes exposure, in a series of several tests.

DISCUSSION.—Walnut shell flour is darker colored when impregnated with extract. It retains this color, its repellency, toxicity and fragrant odor for long periods of time when refrigerated in tightly closed bottles. Exposure to air results in a loss of these properties which is nearly complete by the end of 24 hours. This, combined with considerable variation in the amount of active material present in fruit from different plants, has complicated insecticidal studies.

SUMMARY.—Extract from fruit of *Amorpha fruticosa* plants, previously reported as being repellent for over 12 hours to several species of insects, has also been found to be repellent to the striped cucumber beetle. Further tests on the chinch bug have shown it to be very repellent to this insect. It was but slightly repellent to two species of mosquitoes, *Aëdes aegypti* and *A. albopictus*. Bites were received after 1 to 27 minute exposures.

Little toxic effect was shown on any of the insects during these tests.—10-1-46.

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[1] Valuable data was contributed by Leo A. Jachowski, Jr., Lt. (jg) H(S) U.S.N.R., concerning tests on mosquitoes, and R. R. Walton of the Dept. of Entomology, Okla. Agr. Expt. Sta. in tests on the striped cucumber beetle.

Emulsifiers for Liquid Acaricides[1]

HELEN J. FLUNO, HOWARD A. JONES,[2] and F. M. SNYDER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

To aid in the control of mite, or scrub, typhus among the armed forces, several liquid acaricides were developed for impregnating clothing (Snyder and Morton 1946). For this purpose the use of emulsions appeared to be the most practical. An emulsifier was needed that would give satisfactory emulsions in soft, hard, and sea water. Some of the emulsifiers that had proved satisfactory in emulsions of dimethyl phthalate for use in mosquito-proofing clothing were selected for testing.

To determine the physical stability of the acaricide emulsions, 10 per cent of the emulsifier was added to the liquid acaricides, and an aqueous emulsion was prepared and observed over a period of time. The method was similar to that used for testing DDT emulsions (Jones *et al.* 1946). An emulsion was considered satisfactory if no separation of the oil phase occurred within 2 hours after preparation, but no separation within 24 hours was preferable.

Table 1 shows the results obtained with the various acaricides combined with some of the better emulsifiers. The emulsifiers are referred to by number, as follows:

1. Polymerized glycol monolaurate
2. Polymerized glycol monooleate
3. Polymerized glycol monostearate
4. *Stearate 61-C-2280*, or *75H-14S* (a polyalkylene glycol stearate)
5. *Triton X-100* (polyethylene glycol alkyl aryl ether)
6. *Tween 60* (sorbitan monostearate, polyoxylalkylene derivative)
7. *Tween 80* (sorbitan monooleate, polyoxyalkylene derivative)
8. Equal parts of *Span 20* (sorbitan monolaurate) and *Tween 20* (sorbitan monolaurate, polyoxyalkylene derivative)
9. Equal parts of *Span 60* (sorbitan monostearate) and *Tween 60*.
10. Equal parts of *Span 80* (sorbitan monooleate) and *Tween 80*

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] Now with the Unit of Entomological Research of Dodge & Olcott, Inc., Baltimore, Md.

Table 1.—Physical stability[1] of emulsions containing 5 per cent of acaricide prepared from concentrates[2] containing 90 per cent of acaricide and 10 per cent of emulsifier.

Acaricides	Type of Water	Emulsifiers									
		1	2	3	4	5	6	7	8	9	10
Benzyl benzoate	Distilled	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
	Hard[3]	Fairly Good	Good	Poor	Good	Fairly Good	Good	Good	Good	Good	Good
	Sea[3]	Good	Good	Good	Good	Poor	Good	Good	Good	Good	Good
Dimethyl phthalate	Distilled	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
	Hard	Good	Good	Fairly good	Fair	Poor	Fairly good	Good	Fairly good	Fairly good	Fairly good
	Sea	Good	Good	Fair	Fair	Poor	Fair	Fairly good	Poor	Fairly good	Fair
Dibutyl phthalate	Distilled	Good	Good	Good	Fairly good	Good	Good	Good	Good	Good	Good
	Hard	Good	Good	Good	Fairly good	Fairly good	Good	Good	Fairly good	Good	Good
	Sea	Good	Good	Fairly good	Fairly good	Fairly good	Good	Good	Good	Good	Good
Rutgers 6–12 (2-Ethyl-1,3-hexanediol)	Distilled	Fairly good	Poor	Poor	Fairly good	Good	Poor	Fair	Fairly good	Good	Fair
Indalone (*n*-Butyl mesityl oxide oxalate)	Distilled	Good	Good	Good	Good	Fair	Good	Good	Good	Good	Good
2-Phenylcyclohexanol	Distilled	Good	Very good	Good	Good	Good	Very good	Very good	Good	Good	Good
Dimethyl phthalate, *Rutgers 6–12*, and *Indalone* (equal parts)	Distilled	Fairly good	Good	Fairly good	Good	Fair	Fairly good	Fairly good	Fairly good	Fairly good	Fairly good
	Hard	Good	Good	Fair	Fair	Poor	Poor	Fair	Fair	Fairly good	Fair
	Sea	Fairly good	Fairly good	Fair	Fairly good	Poor	Poor	Poor	Poor	Poor	Poor
Dimethylphthalate, *Rutgers 6–12*, and 2-phenylcyclohexanol (equal parts)	Distilled	Good	Good	Good	Good	Fair	Good	Good	Good	Good	Fairly good
	Sea	Fairly good	Fair	Fair	Fair	Poor	Poor	Fair	Poor	Fairly good	Fair
Dimethylphthalate, *Rutgers 6–12*, and benzyl benzoate (equal parts)	Distilled	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good

[1] "Poor" indicates that separation of oil phase begins immediately; "fair," within 2 hours after preparation; "fairly good," between 2 and 24 hours; "good," no separation of oil phase within 24 hours, only creaming; "very good," either no separation whatever in 2 hour or indistinct creaming.

[2] All concentrates were clear except the following:
1 and 3—Slightly cloudy in dibutyl phthalate.
8—Cloudy in benzyl benzoate and dibutyl phthalate, slightly cloudy in Indalone, and foamy with dimethyl phthalate.
9—Cloudy and undissolved material in benzyl benzoate and dimethyl phthalate, cloudy in dibutyl phthalate, some undissolved material in Indalone.
10—Slightly cloudy in benzyl benzoate.

[3] Artificial hard water contained 500 p.p.m. of magnesium sulfate, 500 p.p.m. of calcium chloride, and 250 p.p.m. of sodium bicarbonate. Natural sea water used.

For use in all types of water with benzyl benzoate, dimethyl phthalate, and dibutyl phthalate, all of which were used as acaricides in the Pacific war area, polymerized glycol monolaurate, polymerized glycol monooleate, and *Tween 80* appeared to be the best emulsifiers tested. The *Span 60-Tween 60* combination also gave good emulsions, but was not completely soluble in these acaricides. For benzyl benzoate only, which has been found to be the most promising of these acaricides, *Stearate 61-C-2280*, *Tween 60*, and the *Span 20-Tween 20* and *Span 80-Tween 80* combinations also gave satisfactory emulsions in all types of water. Benzyl benzoate was more readily emulsified than dimethyl phthalate. *Tween 80* and *Stearate 61-C-2280* were also tested as emulsifiers for 50:50 mixture of benzyl benzoate and dibutyl phthalate, which has been found to be better for the impregnation of clothing than benzyl benzoate alone, and they gave satisfactory emulsions. Several of the emulsifiers formed good emulsions with materials which are also mosquito repellents, such as 2-phenylcyclohexanol, the dimethyl phthalate: *Rutgers* 6-12:*Indalone* mixture, and dimethyl phthalate.

Before these emulsifiers were recommended for use by the armed forces, they were tested alone with distilled and sea water to determine their acaricidal properties. Although none of the emulsifiers listed in table 1 interfered with the acaricidal properties of the toxicants when used under experimental conditions in Florida, before any of them can be used on a large scale for this purpose it will be necessary to test them under field conditions and to determine their possible irritation and toxicity to man. —8-15-46.

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Hexaethyl Tetraphosphate for Control of Mites

L. J. FAYETTE,[1] G. S. HENSILL[1] and C. C. CASSIL[1]

Results of recent experimentation indicate that hexaethyl tetraphosphate merits considerable attention as a commercial control for numerous insects and arachnids causing serious damage to agricultural and garden crops. The acaricidal value of this new insecticide was determined in an experiment conducted at a commercial nursery in San Pablo, California. The two-spotted mite, *Tetranychus bimaculatus* Harvey, was causing considerable damage to plots of rose bushes, the President Hoover variety, located out-of-doors.

A plot containing one hundred and fifty bushes, averaging five feet in height, was divided into three rows and each bush numbered. Thirteen bushes were chosen, five from the first row, four from the second and third rows, and each bush was divided arbitrarily into top, middle, and bottom. Three, five and seven leaves, respectively, were picked at random from these areas. Using a binocular microscope, the number of mites on each leaf, upper and lower surfaces, was recorded, segregating those dead from those alive. No eggs, exo-skeletons, nor fragments of mites were counted.

Two 75 gallon applications of hexaethyl tetraphosphate in a commercial spray, *Vapotone Insect Spray*, containing 50 per cent of the toxic ingredient, were applied at the rate of 1 pint per 100 gallons. The second application was made after a time lapse of 11 days. Five population counts were made, the first on June 13, immediately before the first spray, and the second one on June 14, 24 hours later. The third count was made on June 24, 11 days after the first and immediately before the second spray application, the fourth on June 25, 24 hours later, and the final count on July 5.

No previous studies were made concerning the number of samples necessary for a reliable statistical analysis of the plot. The average coefficient of variation of the five counts was 28.2 per cent which indicates that an adequate number of samples was taken. The accompanying table summarizes the results.

DATE	MITES PER LEAF[2] LIVING	TOTAL
		Mean σ
June 13	52.24	54.06 ± 13.99
June 14	0.45	37.43 ± 8.48
June 24	5.52	34.45 ± 9.92
June 25	0.04	33.30 ± 9.76
July 5	0.07	20.11 ± 6.86

The first application killed 98.6 per cent of the mites, and most of those found alive at the time of subsequent counts were those hatched from eggs observed in the original population. The newly hatched mites were killed by the second spray application before they had reached maturity and could lay eggs. The per cent mortalities were not calculated in every case because there was a continual increase in the mite population. The results are presented in terms of living mites per leaf. It was apparent that hexaethyl tetraphosphate did not kill all the mite eggs although observations made during the study indicate that the mortailty of the eggs was above normal.

The data did not show a significant correlation between the number of mites in the original population and the number of mites 24 hours after spraying, indicating that the number of mites washed off during spraying was not a fraction of the number of mites in the original population.

An analysis of variance showed the apparent slight increase in mites alive per leaf 11 days after the second spray to be insignificant; *i.e.*, the mite population had remained constant because all the eggs had hatched by the time of the second spray application.

The results of this experiment show that hexaethyl tetraphosphate is an effective acaricide and will give commercial control of the two-spotted mite. Generally it would be necessary to apply more than one treatment in order to kill those mites which have hatched from eggs not killed during the initial spray. This experiment indicates that two applications of aqueous spray containing hexaethyl tetraphosphate at 1 to 1600 dilution are sufficient until a reinfestation occurs.

[1] Research Dept. Calif. Spray-Chem. Corp., Richmond, Calif.

[2] The five population counts included a total of 34,970 mites.

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Increase in the Population of *Lecanium pruinosum* on English Walnuts Following Applications of DDT Sprays

A. E. MICHELBACHER, CLARK SWANSON and W. W. MIDDLEKAUFF, *University of California, Berkeley*

At Linden, California DDT water suspension sprays were used during the summer of 1945 to control the codling moth on the Payne variety of walnut. The composition of the spray per 100 gallons of water was as follows:

DDT 20 per cent wettable powder . . . . . 5 pounds
Colloidal DDT depositor . . . 0.33 pound 1st spray; 0.5 pound 2nd spray
Light medium oil emulsion . . 0.33 gallon

Order of mixing: DDT added when water was up to the agitator rod, then depositor, followed by the oil.

One and two spray treatments were compared In one case, trees were sprayed on May 4 and in the other, on May 4 and again on May 31. Each of the treatments were replicated seven times along with other treatments in a 7 by 7 latin square which consisted of single tree plots. Similar sprays were also applied at the same time to two commercial blocks, each consisting of 56 trees. The sprays were applied at 600 pounds' pressure with automatic sprayers equipped with 25 foot towers. Approximately 55 gallons of spray were used per tree for each application.

Both the one and two spray treatments resulted in excellent control of the codling moth. Where the two sprays were applied, it was extremely difficult to find a single infested nut in the harvested crop.

The treatment also resulted in the control of the walnut aphid, *Chromaphis juglandicola* (Kalt.). The reduction in population was more marked where the sprays were applied on a commercial scale than where they were applied to the single trees in the replicated experiment. The aphid control obtained was the best we have experienced with DDT. Where used elsewhere on walnuts, DDT has resulted in a fair to good initial kill, which has been followed by a serious increase in the aphid population.

There was a considerable increase in the mite population late in the season on those trees receiving DDT. This increase was more marked on the commercial blocks than in the single tree experiment.

On May 10, 1946 the trees sprayed with DDT were examined. It was noted that they were much more heavily infested with the frosted scale, *Lecanium pruinosum* Coquillett than were any of the surrounding trees. Relative scale populations were determined by counting the number of live scales on terminal twigs. All scales were counted back to the first lateral twig. The average number of scales found per twig, and the number of twigs counted, were as follows:

	TWIGS	SCALES
One spray DDT, commercial block.	96	7.5
Trees surrounding the one spray DDT commercial block	48	0.54
Two spray DDT, commercial block	96	6.0
Trees surrounding the two spray DDT commercial block.....	48	0.37
One spray DDT replicated single tree plots.....	42	2.1
Two spray DDT replicated single tree plots.....	42	1.8
Check trees in replicated single tree experiment.....	42	0.54

From the above it is seen that the scale population was much heavier on those trees which were sprayed with DDT. Further, the population was larger in the commercial blocks than it was in the single tree replicated plots. Apparently many of the advantages as well as the disadvantages connected with the use of DDT are magnified when it is applied to commercial blocks as compared to single tree replicated plots. This certainly appeared to be the case with the frosted scale. The same thing also occurred with the orchard mite, and in the case of the walnut aphid, control appeared better in the commercial blocks than in the single tree replicated plots.

Di(4,Chlorophenoxy) Methane for Control of Citrus Red Mite

LEE R. JEPPSON, *Citrus Experiment Station, Riverside, California*[1]

Oil sprays and dinitro-o-cyclohexylphenol (2-cyclohexyl 4,6-dinitrophenol) sprays and dusts are generally relied upon for the control of the citrus red mite, *Paratetranychus citri* McG., on citrus in California. Although oil sprays have given good control there are many conditions in which it is undesirable to apply oil to citrus trees at the concentrations necessary for adequate mite control. The dicyclohexylamine salt of dinitro-o-cyclohexylphenol at concentrations of 1.7 per cent in a dust, *DM-Dust D-8*, and 20 per cent in a spray concentration, *DN-111*, are used with generally satisfactory mite control but under high temperature conditions they may cause plant injury and they cannot be combined with most of the insecticides and fungicides commonly used on citrus trees.

Di(4,chlorophenoxy) methane was found to be toxic to the citrus red mite in tests made in the laboratory by Ray Korsmeier during April 1944.[2] In March, 1945, tests were made by the author which confirmed Mr. Korsmeier's results. At that time rather extensive laboratory and field studies were initiated, the results of which have shown that this material exhibits not only immediate but residual toxicity to these mites. It has also been found to possess other desirable characteristics which lend to the production of sprays and dusts for the control of the citrus and other plant mites.

Di(4,chlorophenoxy) methane is soluble at approximately 4 per cent in kerosene or the regular spray oils and up to 30 per cent in *Velsicol AR-60*, tetralin, and similar aromatic solvents. This compound dissolved in either of the above solvents to give a dilutes spray concentration of two-thirds of a pound or more of the toxicant per 100 gallons of water consistently gave a complete kill of red mite eggs in laboratory tests.

Laboratory and field-laboratory tests have been made to measure the residual toxicity of this compound to the citrus red mite. In these tests, mites were transferred to fruit at intervals after treatment. When dissolved in kerosene or *Velsicol AR-60* and applied at 1 pound per 100 gallons of diluted spray, mortalities of 100 per cent have been obtained after 60 days under insectary conditions and under field conditions from 10 to 30 days. The results from the first year's field program suggest that the residual toxicity is more prolonged during the winter than during the summer season.

Nearly 1000 pounds of di(4,chlorophenoxy) methane have been applied in spray emulsions to citrus trees during 1945 to June 1946. No injury to the trees attributable to the treatments has been observed in any of the tests. The results of experiments thus far conducted in the control of the citrus red mite with emulsions containing this compound at one pound per 100 gallons of spray have been comparable with the conventional oil sprays and have given more consistent control than *DN-111*.

Although spray suspensions or dusts containing di(4,chlorophenoxy) methane are less toxic to the eggs of the citrus red mite than kerosene emulsions, field tests indicate that it has sufficient residual toxicity to prevent the development of the mites which hatch after the time of application. Concentrations of one pound per 100 gallons of spray and dusts containing 4 per cent or more of the active ingredient have given satisfactory control in preliminary field tests.

Further work on di(4,chlorophenoxy) methane is being continued in order to determine the most effective and practical combinations and dosages to be used each season of the year in the various localities where the citrus red mite is a pest in California. Combinations of this compound with insecticides and fungicides now in use are being investigated to determine their compatibilities.

[1] Thanks are due the Dow Chemical Company for supplying the di(4,chlorophenoxy) methane and especially to Drs. Britton, Kagy and Mr. Korsmeier for their suggestions and assistance.

[2] Unpublished notes on file at the University of California Citrus Experiment Station, Riverside, California.

A New Host for *Cybocephalus* sp., a Predator of Diaspine Coccidae

LEO KARTMAN,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Beetles of the cybocephalid genus *Cybocephalus* occur throughout the subtropical and tropical regions of the world, feeding mainly upon diaspine Coccidae and species of Aleyrodidae. Species of this predator have been reported as far north as Japan and as far south as Cape Town. Probably about a dozen species are known.

Possibly two species occur in the United States: *Cybocephalus californicus* Horn is reported from the Southwest and has been collected in California from Yuba County to San Diego County, and *C. nigritulus* Lec. frequents the Southeast. The taxonomy of the genus, however, is confused, and it has been suggested that the types of *californicus* and *nigritulus* may be opposite sexes of the same species.

Herbert (1920) has reported *Cybocephalus californicus* Horn as a predator upon the cypress bark scale, *Ehrhornia cupressi* (Ehr.), in California. Riley (1882) recorded two species feeding upon *Chionaspis* in western North America. Balachowsky (1928) and Peyerimhoff (1931) have reported several species predacious on the parlatoria date scale, *Parlatoria blanchardii* (Targ.), in North Africa and the Near East. Silvestri (1910) has given an account of *Cybocephalus rufifrons* Reit. which feeds on the eggs of the white peach scale *Pseudaulacaspis pentagona* (Targ.). Clausen & Berry (1932) have recorded the genus as predacious on the citrus black fly and other Aleyrodidae in tropical Asia. One species is rather common on *Aleurocanthus* in Java.

Very little is known of the biology of this genus. Silvestri (1910) gives an account of the habits of *Cybocephalus rufifrons* Reit, which lays its eggs beneath the female scales of the white peach scale. Clausen & Berry (1932) made observations on an undetermined species in Java, the larvae of which were white and remained upon the leaf during the entire feeding period. Pupation occurred in the soil without the formation of a cocoon. Flanders (1934) has recorded the life history of an undetermined species imported from the Orient to feed on red scale in California. He states that pupation occurs in the soil, with the formation of a round, parchment-like white cocoon. The total life cycle at 82° F. lasted about 24 days. Balachowsky (1928) states that the adults of *C. seminulum* Baudi are very strong fliers.

During April of 1942 small black beetles were observed (Ferris 1941) in a Chico, Calif., orchard on almond trees heavily infested with the Hall scale, *Nilotaspis halli* (Green). On closer inspection these beetles were seen to be feeding on the scale. E. A. Chapin, of the U. S. National Museum, determined the predator as *Cybocephalus* sp. and indicated that it might be *C. californicus*. However, the specific status is here used only tentatively for the reasons cited above.

The adult beetle is exceedingly small, being approximately 1 mm. long and 0.8 mm. in width. This size is only very slightly larger than the adult scale host. The beetle is rather difficult to locate because of its habit of hiding in the cracks and crevices of rough bark. This habit is an advantage, since its small size allows it to seek out the scale located in well protected bark recesses.

Microscopic observations showed that the adult beetle usually attacks the scale vigorously, works through the case with its stout mandibles, and then produces a large gap in the soft scale body. It subsequently proceeds to bury its mouth parts, and even a portion of its head, in the opening and remains thus for an appreciable time, apparently imbibing the fluid content of the scale. Gravid female scales seemed especially to be the prey of the beetle, whereas migrating larvae were ignored.

In order to arrive at some preliminary estimate of the feeding capacity of the predator, 12 beetles were confined singly, each with 10 live adult female scales, on squares of bark. This material was held at room temperature and the bark kept fresh by moistening.

Over a period of about 36 hours an average of 7.08 scales per beetle were consumed. Three of the beetles tested consumed all of the hosts allotted them.

Field observations were made on the abundance of the predator. Each tree was given a 30-minute inspection from crown to base. The beetle seemed to be confined chiefly to older parts of the tree in rough bark. This is remarkably correlated with the habits of the host. A direct relation between predator abundance and intensity of scale infestation was indicated.

Actual counts revealed that *Cybocephalus* was present in very small numbers. Specimens found averaged about 0.40 adult beetle per tree lightly infested with the host, and about 3.40 beetles per tree with heavy scale infestation. This meagre population may have been due to the effects of control operations against the scale. Life-history studies were not feasible in view of this lack of material.

These observations on *Cybocephalus* show it to be a predator of diaspine Coccidae in many parts of the world. Whether it could prove an efficient factor in biological control cannot be surmised at this time. Obviously, work on this genus is at present limited.

[1] The writer expresses his appreciation for helpful suggestions from B. A. Porter and C. P. Clausen.

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Effect of Hexachlorocyclohexane on Onion Seedlings

W. S. McLEOD, *The University of Manitoba, Winnipeg*

In the course of an experiment on onion maggot (McLeod 1946) it was noticed that pelleting the onion seed with an equivalent weight of 20 per cent of crude hexachlorocyclohexane in gypsum prevented the growth of any onion seedlings (Treatment No. 17). This note records an attempt to discover what had happened in this particular test.

Accordingly, in January of 1946, a greenhouse test was performed. Soil was weighed out in two-pound portions. A 20 per cent dust of crude hexachlorocyclohexane in gypsum was mixed with these portions of soil in quantities which varied from 0.5 gram to 512 grams. Eleven pots were filled with the various mixtures while a pot filled with untreated soil was used as a check. Each pot received 200 Ebenezer onion seeds and observations were made every second day by pulling and examining 2 seeds or seedlings from each pot. Growth was good in the check pot but all others showed a marked effect from the hexachlorocyclohexane.

It was therefore decided to repeat the experiment immediately with greatly reduced dosages.

In the second experiment, soil was once again measured out in 2-pound portions. To these were added, respectively, the following amounts of 20 per cent hexachlorocyclohexane in gypsum: 0 (check), 0.01 gm., 0.03 gm., 0.06 gm., 0.12 gm. 0.25 gm., 0.5 gm., 1 gm., 2 gm., 4 gm., 8 gm., and 32 gm. Each pot was planted with 100 onion seeds. It was observed that, contrary to expectations, seed in all pots germinated normally. About the time the seedlings in the check pot were an inch in height a distinct effect of the hexachlorocyclohexane could be noted. All pots containing 0.5 gm. or less of the 20 per cent dust showed healthy seedlings with no apparent difference between treatments. The one which had received 1 gm. had a normal number of shoots showing above the surface of the soil but these shoots were shorter and thicker than those already noted. The sample which contained 2 gm. had very few shoots visible above the surface and these were considerably thickened at the base. The remaining 4 pots, all of which contained 4 gm. or more of dust, had no seedlings showing above the surface; those seedlings which were removed for examination showed the characteristic thickening of the shoot and in addition, the tip of the rootlet showed a marked browning.

Later observation showed that the above-mentioned effects continued to become more pronounced. At the termination of the experiment it was thought that the plants in the 0.5 gm. treatment showed a very slight thickening of the shoot, a condition which had not been apparent at an early date.

These results would indicate that applications of hexachlorocyclohexane to the soil may be not without hazard. Applications should always be the minimum quantity which will produce satisfactory control of the pest concerned. Information on the rate of volatilization of the chemical must be secured before it will be safe to recommend the material for the control of such a pest as the onion maggot where applications must be made to the soil at the base of the plant.—7-6-46.

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Neurocolpus nubilus, a Cotton Pest

F. F. BIBBY, *Smithville, Mississippi*

Neurocolpus nubilus (Say)[1] (Miridae) apparently caused serious damage to cotton in Mississippi during 1946 and did more toward causing yield there to fall below average than any other insect pest.

In Tunica, Coahoma, and Monroe Counties there were many fields showing typical mirid-damage in which *Neurocolpus nubilus* was in greater abundance than any other mirid. In some of the fields it was the only one found; in others, the mirids *Adelphocoris rapidus* (Say), *Lygus oblineatus* (Say), and *Psallus seriatus* (Reuter) were along with *N. nubilus* and, no doubt, contributed to the damage.

The damage was similar to combined damage of *Psallus seriatus* and *Adelphocoris rapidus*. One characteristic not common to either, or to that of *Lygus oblineatus*, was yellowing of exposed petal-portion of immature squares.

Neurocolpus nubilus was collected from *Croton capitatus* Mich.[2] in Pemiscot County, Missouri, in October, 1946, in association with *Psallus seriatus*.—11-7-46.

[1] Determined by Mr. J. M. Langston, State College, Mississippi.
[2] Determined by Dr. J. Ewan, Beltsville, Maryland.

Unusual Feeding Injury by Corn Earworms

MARTIN H. MUMA, *University of Nebraska, Lincoln*

Unsual injury to corn stalks by the corn earworm *Heliothis armigera* (Hbn.), was observed on October 15 and 16, 1946 in south central Nebraska. While surveying for infestations of the southwestern corn borer, *Diatraea grandiosella* Dyar, rather frequent breakage of stalks just above, at, or just below the ear was noted. Investigation disclosed large, blackened frass-filled cavities just above the joints at which the lodging occurred. These tunnels seldom extended more than an inch or two into the internodal area and in most cases consisted of a simple hollowed cavity. In some instances, however, definite convoluted tunnels were found. Most of the tunnels or cavities were partially or completely filled with large, moist, foul frass but contained no larvae. Careful shredding of a considerable number of injured stalks revealed corn earworm larvae in about 20 per cent of the stalks. These larvae were apparently from a late generation as nearly half of them were only half to two-thirds grown. The accompanying photograph shows the type of stalk injury caused by these larvae.

Although no definite survey was made to determine the extent of this injury, estimates of damage were made in the 30 fields examined. The fields were located in Thayer, Nuckolls, Webster, Franklin, Harlan, Furnas, Phelps, Kearney, and Adams Counties. All fields examined had some breakage due

FIG. 1.—Corn earworm damage to cornstalks.

to the earworm. Three fields had an estimated 5 per cent of the stalks lodged but in most cases the injury was estimated at 1 per cent or less.

The reason for this unusual type of injury by the corn earworm is not definitely known. A knowledge of the weather and crop conditions in the area does, however, give a possible explanation. The 1946 corn season in the affected area was long. This was caused by a dry spring and a rainy fall that prolonged the growing season well into October. Under this condition a late brood of earworms was apparently produced. At this time the ears were mature. Subfreezing temperatures killed corn leaves and other cultivated and wild food plants, forcing the partly grown worms to feed in the late cornstalks that were still somewhat green.—11-4-46.

Benzene Hexachloride as an Ovicide for the Short-nosed Ox Louse

R. W. WELLS and W. L. BARRETT, JR., *U.S.D.A. Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Results are given of tests on the use of benzene hexachloride or gamma isomer of (hexachlorocyclohexane) as an ovicide for the short-nosed ox louse, *Haematopinus eurysternus* Nitz.

Wettable hexachlorocyclohexane powder aggregate, labeled as containing 7.5 per cent of the gamma isomer, was used as suspensions in water with the indicated levels of gamma concentration.

For tests *in vitro*, patches of egg-infested hair were plucked from cattle. Unhatched eggs were sorted and then counted out into lots of 100. Each hair was clipped close to the ends of the egg, thus leaving the egg attached to a short section of hair. The batches of eggs were treated by immersing and gently agitating for 1 minute in 25 ml. of suspensions containing 1.0 and 0.1 per cent of the gamma isomer. The eggs were removed from the suspensions by screening with 60-mesh bolting cloth. After drying for a few minutes on filter paper at room temperature, the eggs were placed in ventilated paper pill boxes and held at different humidities controlled by sulfuric acid in a constant temperature of 30° C. Untreated eggs were similarly held as checks.

The relative humidites in which the eggs were incubated were 38.9, 75, 87.9, and 94.9. Of the untreated eggs at these humidities, the percentages that hatched were 94, 84, 78, and 20, respectively. However, at 94.9 per cent humidity fungus developed in abundance on the eggs. None of the treated eggs held in the same environments hatched.

On the laboratory premises two infested cattle were sprayed to saturation with an aqueous suspension containing 0.1 per cent of the gamma isomer. Untreated eggs taken before spraying yielded 76 and 63 per cent hatch at 30°C. and 75 per cent humidity, whereas eggs removed 1 hour after spraying and placed in the same environment yielded no hatch.

On a ranch one heavily infested cow was sprayed to saturation with a 0.1 per cent suspension of the same material. The infestation was eradicated by one treatment.

In other *in vitro* tests 100 per cent of the eggs were killed with gamma benzene hexachloride at concentrations of 0.05 and 0.01 per cent, but the number of viable eggs available was not adequate for entirely satisfactory conclusions.

Most of these tests were conducted in March and April 1946—11-5-46.

Control of Grasshoppers Injuring Apple Orchards

CASTILLO GRAHAM and ERNEST N. CORY, *University of Maryland, College Park*

A mixed infestation of two species of grasshoppers, *Melanoplus femurrubrum* DeGeer and *M. differentialis* Thomas, appeared in apple orchards in Washington County July 15, 1946, in destructive numbers. The standard poison-bran bait applied in late afternoon and evening in several orchards failed to give satisfactory control.

By August 10 the hoppers were causing complete defoliation of apple trees in many orchards. Sprays containing nicotine sulphate and arsenate of lead, various strengths of DDT wettable powder, DDT emulsion, and of a material known as *20X*, which contained pyrethrum, proved ineffective. A commercial spray *DX*, containing DDT, rotenone and pyrethrum, when used at 2 quarts to 100 gallons of spray and applied to the trees and ground cover, gave approximately 85 per cent kill. Benzene hexachloride, containing 12 per cent gamma isomer, when used at strengths of 1 to 4 lbs. per 100 gallons of spray, applied to both trees and ground cover, gave approximately 100 per cent kill within 6 hours. When used at the strength of 1.5 lbs. on the ground cover only, approximately 95 per cent kill was obtained. Several hundred acres of apple orchards in Western Maryland were sprayed with this material, and in all cases good commercial control was obtained with one application. It required approximately 400 gallons for an acre of ground cover.

At the time the applications of benzene hexachloride were applied it was deemed advisable to avoid spraying the fruit due to the undesirable odor of the material. However, samples of apples from trees sprayed August 13, 1946 with as much as 4 lbs. of the material per 100 gallons of spray, had no detectable odor at harvest time.—12-2-46.

Controlling the Fall Armyworm in Sweet Corn and Popcorn with DDT

R. A. BLANCHARD, T. R. CHAMBERLIN, and A. F. SATTERTHWAIT,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In the East St. Louis, Ill., area the fall armyworm, *Laphygma frugiperda* (A. and S.), often causes severe damage to sweet corn maturing after September 1. In Mississippi, where the work on popcorn reported herein was carried on, the fall armyworm may attack the whorls of growing corn as early as May and continue until fall, severely damaging the ears. Most of the attacks, however, have been reported in June, July, and August, when the worms feed mostly in the leaf whorls. Under some conditions such feeding in the whorls may ruin whole fields. In both Illinois and Mississippi the fall armyworm and the corn earworm, *Heliothis armigera* (Hbn.), often attack the same ears. Their combined damage may be very severe since, although the fall armyworm may enter the ears through the silk channel, as the earworm usually does, it also often bores into the side of the ear. When abundant, it thus further reduces the marketability of sweet corn by making the husks unsightly.

In 1944 and again in 1945 in the East St. Louis area during the course of experiments with DDT for control of the corn earworm in sweet corn ears, observations were also made on the effectiveness of DDT against the fall armyworm. Where the fall armyworm was present, oil solutions and emulsions containing 2 per cent of DDT were used in the tests both years. Two methods of applying the insecticides to the ears were used—(1) injection into the silk channels and (2) atomization upon the ears and silks by means of a paint-spray gun.

In 1944 only a few fall armyworm larvae were still in the corn ears in any of the treated or check plots examined at harvest time. It was therefore necessary to estimate the degree of control obtained largely on the basis of scarcity or abundance of the type of damage characteristic of this insect. The results indicated, however, that 2 per cent of DDT in white mineral oil (80–90 seconds Saybolt) was very effective for control of the fall armyworm, as well as the earworm, and that ears treated by atomization were somewhat more effectively protected than those treated by injection. Certain DDT emulsions also gave good control of both the armyworm and the earworm, especially where they were applied by atomization. The formulas for these emulsions are not given, because they were not entirely satisfactory in other respects.

In 1945 more positive data on control of the fall armyworm were obtained in experiments in which several different treatments were tested on triplicate plots. Since a considerable population of fall armyworms was present at harvest time on the plots that had received no treatment or an unsuccessful one, the effectiveness of the different treatments could be compared on the basis of the numbers of worms present and the extent of characteristic armyworm injury.

Ears treated with mineral oil (85–95 seconds Saybolt) containing 2 per cent of DDT at the rate of 0.5 ml. per ear by injection, or 1.0 ml. per ear by atomization,[2] had neither armyworm damage nor armyworm larvae at harvest time. Almost perfect control of the corn earworm was obtained by this treatment.

The three emulsions tested gave somewhat better control of the fall armyworm than of the earworm. One emulsion gave apparently perfect control of the fall armyworm when a total of 1 ml.–0.5 ml. to each side—was applied to each ear. This was a relatively stable emulsion containing the following ingredients: Water-dispersible powder containing 90 per cent of DDT, 2 per cent; a condensation product of ethylene oxide and an alkylated cresol (*Igepal CA Extra High Concentrate*), 1 per cent; white mineral oil (85–95 seconds Saybolt) (Marcol JX), 10 per cent; and water, 87 per cent. Only one fall armyworm was present in 35 years to which this emulsion was applied at the rate of 0.5 ml. per ear—either 0.25 ml. from each side of 0.5 ml. from one side. In the three tests with this emulsion from 69.4 to 88.2 per cent of the ears were undamaged and contained only 0.14, 0.22, and 0.11 earworm larva per ear. All the ears on the untreated check plots were damaged by either the earworm or the fall armyworm, or both, and averaged 0.64 fall armyworm and 0.89 earworm per ear when harvested. The type of damage on the untreated ears indicated that the fall armyworm had fed on a large percentage of them.

In 1945 experiments were conducted near State College, Miss., on young popcorn plants heavily infested with fall armyworms, which were feeding in the whorls and tassels. Dusts containing 1 to 9 per cent of DDT in pyrophyllite, a bran bait containing DDT, and a water emulsion containing 2 per cent of DDT were used. The bait formula was 2 ounces of DDT, 0.35 pint (168 ml.) of dark cane cooking molasses, 3 pounds of bran, and 1.5 pints of water. The emulsion contained 9.48 gm. of DDT, 18.96 ml. of xylene, 0.75 ml. of *Igepal CA Extra High Concentrate*, and water to make 1 pint.

The dusts were applied with a small plunger-type duster in sufficient quantity to penetrate the whorls and tassels of the plants. The amount per plant varied somewhat according to the size of the plant and the extent to which feeding had extended outside the whorls on the leaves and tassels. It is estimated that the average rate was 10 pounds per acre or less. Enough of the emulsion was used to moisten the tassels and whorls and provide some excess, which ran down into the middle of the whorls. The amount averaged about 1 ml. per plant.

No control was obtained with any of the dusts. The bran bait gave excellent control when dropped into the whorls of the plants, and the emulsion gave some control, but was judged much inferior to the bait.

Whether DDT can safely be used on sweet corn grown for market and on popcorn has not been fully determined. Although the foregoing treatments apparently resulted in little or no residual deposit of DDT on the sweet corn kernels, chemical analyses indicated that considerable quantities remained on other parts of both plants up to 26 days after treatment. Until further information is available on the magnitude and hazards of these residues, DDT should not be applied to corn plants, portions of which may be used for human or animal food.—10-23-46.

[1] The authors gratefully acknowledge assistance in the field work by W. A. Douglas, of the Bureau of Entomology and Plant Quarantine and by J. Murray Brown, owner of the experimental field in Mississippi.

[2] No plots atomized at 0.5 ml. per ear were included in teseh tests.

Seasonal Cycle and Control of the Pine Tip Moth

F. A. FENTON and M. AFANASIEV, *Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma*

For several years, ornamental and experimental plantings of pines near Stillwater, Oklahoma, have been seriously injured by the Nantucket variety of the pine tip moth.[1] The following is a brief report on biological and control studies made at Stillwater during 1946.

SEASONAL CYCLE.—Winter is passed in the pupal stage in pine tips. There were four definite periods of moth emergence as follows: March 19 to April 9; June 1 to 10; July 10 to 24, and September 5 to 17. All larvae of the first and second generations pupatec shortly after the end of the larval feeding period but only part of those of the third generation pupated. The rest remained as larvae until early in October when they pupated. No moths had emerged from these pupae by October 24, so it is assumed they will overwinter. Moths of the third generation laid eggs and by October 24, 51 per cent of the larvae which hatched from these eggs had pupated. There were therefore, two complete generations and partial third and fourth generations in Stillwater in 1946. The overwintering pupae were derived from two generations.

CONTROL.—Emergence of moths was used to time sprays. These were applied March 30, June 7, and July 19. A water dispersible DDT (50 per cent strength) was used at 1, 0.48 and 0.118 per cent concentrations and also the following formulation: summer oil (*Superla*) 3.75 pints, 40 per cent nicotine sulfate (*Black Leaf 40*) 0.8 pint, to 50 gallons of water. The trees were sprayed with power sprayers at 400 to 600 pounds pressure so that the tips of the branches were thoroughly drenched. Most of the pines were less than 5 feet tall. Shortleaf pine, *Pinus echinata*, was sprayed because it is very susceptible to the pine tip moth. Each of the plots consisted of not over 60 trees in a solid block except in the oil-nicotine plot where the trees were scattered. All plots were in two blocks containing several other varieties.

The results are shown in table 1. The examination made May 9 showed that control was perfect with a 0.48 per cent DDT spray, and that the control with the oil-nicotine was inferior to the two DDT treatments. Plot 1 was sprayed June 7 to control the second generation while plot 2 was left to determine possible residual effect of the March 30 spray treatment. The infestation count made July 5 again proved the effectiveness of the 0.48 per cent DDT treatment and also the fact that the March 30 DDT spray had lost its effect. A third spray was applied to plots 1 and 2 July 19, using a 0.118 per cent DDT concentration. This reduced the infestation in plot 2 and held it down in plot 1.

The trees were not sprayed to control the fourth generation. As a result, the infestation increased tremendously in plots 1 and 2. The heavy infestation in plot 2 could have been due in part to the fact that it was the nearest to the non-sprayed or check plot.

The results of this preliminary test show that a water dispersisle DDT spray at 0.48 per cent strength will effectively control the Nantucket variety of the pine tip moth. The spray application must be timed to control the young larvae before they can penetrate into the rapidly growing terminals. This can be determined best by observations on moth emergence. The spray must be directed into the terminals with considerable force so that it can penetrate into the cluster of pine needles. Where reinfestations in small blocks are possible, it is necessary to spray for each generation, or four times However, if large blocks can be sprayed and all infested trees treated in the immediate vicinity, one or two properly timed applications would appear to be sufficient to give protection.

[1] Determined as *Rhyacionia frustrana* (Comst.) by the U. S. National Museum.

Table 1.—Comparative effectiveness of three spray treatments for controlling the pine tip moth Stillwater, Okla., 1946.

Plot No.	Spray Mixtures Used and Dates of Treatment	Per Cent Infested Tips[1] for— 1st Generation May 9	2nd Generation July 5	3rd Generation Aug. 29	4th Generation Oct. 24
1	DDT, 0.48% Mar. 30, June 7. DDT, 0.118 July 19.	0	1	3	52
	DDT, 1% Mar. 30. DDT, 0.118% July 19.	1	39	15.2	70
3	Check	72	62	74	90
4	*Superla* oil 3.75 pints, *Black Leaf 40* 0.8 pints, water 50 gals. Mar. 30.	16	—	—	—

[1] Infestations determined by examinations of randomized samples taken in each plot.

Laboratory Tests in Controlling Pillbugs[1]

F. R. SHAW, A. I. BOURNE, and W. B. HATHAWAY, *Massachusetts State College, Amherst*

Species of Crustaceans of the families Oniscidae and Armadillidiidae have frequently caused severe damage in greenhouses. In an attempt to find a satisfactory control for these pests and as a preliminary to experiments with DDT on plants under actual greenhouse conditions, laboratory tests have been conducted to determine the effectiveness of DDT as a control measure for two species of *Armadillidiidae, Armadillidium vulgare* Latr. and *A. nasatum* Budde-Lund. The results obtained are based upon three tests conducted successively.

The following is a list of the percentages and the types of DDT used throughout the experiments:

Gesarol A3 dust 3 per cent DDT
Neocid A5 powder, 5 per cent DDT
Larvicide, dust, 10 per cent DDT
Gesarol dust conc, 40 per cent DDT

Throughout the experiments the Crustaceans were maintained in 3-ounce salve boxes in which small amounts of manure obtained from greenhouse benches were placed to serve as food. The manure was moistened to supply essential moisture. Five specimens of the Crustaceans were placed in each container.

In each of the three successive tests, four containers were included for each percentage of DDT to provide the conditions listed below:

Pillbugs in constant contact with DDT, container covered.

[1] The suggestions of Dr. H. L. Sweetman are acknowledged.

Table 1.—The average number of hours required for each percentage of DDT to produce moribund and dead specimens under four container conditions.[1]

Container Condition	Per Cent of DDT							
	3		5		10		40	
	Moribund	Dead	Moribund	Dead	Moribund	Dead	Moribund	Dead
	hours	*hours*	*hours*	*hours*	*hours*	*hours*	*hours*	*hours*
Constant contact, container covered	36	68	32	64	20	44	24	40
Constant contact, container not covered	40	56	24	36	28	44	28	32
Non-constant contact, container covered	32	48	56	72	32	56	60	76
Non-constant contact, container not covered	36	44	44	60	48	60	44	64

[1] The average number of hours was obtained by averaging the results of the three tests.

Pillbugs in constant contact with DDT, container uncovered.
Pillbugs in non-constant contact with DDT, container covered.
Pillbugs in non-constant contact with DDT, container uncovered.

It was desired to determine whether or not constant contact with DDT would produce more rapid mortality than non-constant contact with DDT and to discover whether or not the fluctuations of humidity in greenhouses would hamper the toxic action of the DDT or, because of a lack of sufficient moisture, hasten the death of the Crustaceans. An attempt was made to gain this information by creating the four conditions listed above. In the case of the specimens in constant contact with DDT, one gram of each strength of DDT was placed on the bottom of its respective container before the specimens were introduced. As previously stated, a small piece of moistened manure was placed in each container. To provide the conditions for non-constant contact with DDT, the specimens were placed in a petri dish and DDT was dusted over them by means of a salt shaker containing successively the various percentages of DDT. The specimens were then placed in the proper containers. Containers were prepared in covered and uncovered conditions in an effort to obtain information concerning the effect of humidity fluctuation. Tin covers closed the covered containers while the uncovered containers had placed over them pieces of cheese cloth held in position by rubber bands. Four check containers were maintained for each of the three tests, a check container for each condition. Each test was conducted in a greenhouse so that proper conditions of temperature and humidity might be approximated.

Observations were made every 12 hours until specimens in all the containers were dead and it was certain that no recovery occurred. A specimen was termed active as long as it was capable of making coordinated movements. When coordinated movements were no longer possible, a specimen was termed moribund. A specimen presumably lost its ability to act as a pest by feeding on plants when this condition was reached. Death was recorded when there was no movement. It was found that death could be accurately ascertained by noting the response of the antennae to the touch of a forceps. Movement of the antennae frequently occurred when no other movement was noticeable.

Special forms were prepared on which all data were recorded. These data were later expressed graphically and it is from these prepared graphs that our conclusions are drawn.

Discussion of Results.—A few of our results are stated in the form of generalizations while others are stated more specifically. Table 1 shows the results of the experiments upon which our discussion is based. All of our results are listed below.

1. The validity of the tests is assumed as specimens in all check containers were still living several weeks after the completion of the tests.

2. All percentages and types of DDT produced death of the Crustaceans.

3. Complete kill of all specimens within a given container required from 1 to 5 days.

4. On the whole, the specimens in constant contact with DDT were killed sooner than those not continually exposed to DDT although the difference in the results between constant contact and non-constant contact with DDT was not sufficient to interfere with control under greenhouse conditions.

5. Variation in humidity under greenhouse conditions had no appreciable effect on the killing effectiveness of the DDT or the length of life of the Crustaceans for the duration of the tests.

6. DDT in 3 per cent strength might be selected as the optimum concentration of DDT to use against pillbugs. This per cent of DDT caused death of all the specimens of pillbugs and it would, moreover, be the most economical strength to use. Percentages lower than 3 per cent might be effective.

7. A study of table 1 shows us that, on the whole, the specimens in constant contact with DDT were killed more rapidly as the percentage of DDT was increased. In the case of specimens not continually exposed to DDT, the specimens were killed less rapidly as the percentage of DDT was increased. We might conclude that the inert ingredient serving as a sticker causes a greater amount of DDT to adhere to the pillbugs and hence results in more rapid death even when the per cent of DDT is less.—7-11-46.

Insects Attacking Cole Crops in Louisiana[1]

P. K. HARRISON, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[2]

It is common knowledge among growers of cabbage, cauliflower, and related crops which are grown extensively in Louisiana that these plants are attacked throughout both the spring and the fall growing seasons by the common green cabbage caterpillars—namely, the cabbage looper, the imported cabbage worm, and the larvae of the diamondback moth. In a study of these cabbage caterpillars at Baton Rouge (Harrison & Brubaker 1943) the total population and relative abundance of the different species varied considerably with the plant and the season. Moreover, general observations indicated that the number of green caterpillars supported by the plants was due largely to factors other than the type of plant, and consequently that the relative abundance of the caterpillars did not indicate accurately the host preference. However, the damage to these crops is not always confined to that caused by the common green caterpillars, because a number of other species of insects often attack these crops and sometimes do considerable damage.

During the fall seasons from 1939 through 1941, when studies were being conducted at Baton Rouge, La., on the relative abundance of the green cabbage caterpillars on cole crops grown under similar conditions, the following crops were used: Green cabbage, red cabbage, collards, cauliflower, kale, broccoli, brussels sprouts, and kohlrabi. Each of these crops was planted in eight plots 25 feet long and 8 feet wide, and each plot contained two rows. An attempt was made to give each crop an equal chance for infestation by arranging the 64 plots in a latin square, by planting kohlrabi, a small plant, 9 inches apart in the row and the other crops 18 inches apart, and by protecting the plantings during the early stages of growth from depredations by any species that might interfere with the stand or the normal growth of the plants, by dusting with cryolite-talc (3–1) or calcium arsenate-paris green (10–1). These applications were discontinued when the stand of plants was established in order to minimize interference with the subsequent caterpillar infestation. Twenty plants per plot were examined at weekly intervals, and all species found were recorded.

The insects found feeding on these crops are listed in table 1.

During both the spring and the fall growing seasons from 1932 through 1943, when methods for the control of caterpillars on green cabbage were being studied, all the species found on this crop were recorded. In addition to the 17 species listed in table 1 as attacking green cabbage during the 3 fall seasons, 14 additional species, including two additional orders (Thysanoptera and Hymenoptera) were found on this crop, making a total of 31 species

[1] In cooperation with the Louisiana Agricultural Experiment Station.

[2] Acknowledgement is made to C. E. Smith, under whose supervision the work was done, for his advice and cooperation in the work; also to the various taxonomists of the Division of Insect Identification for determining most of the species.

Table 1.—Insects found feeding on cole crops in experimental plots at Baton Rouge, La., during the fall seasons, 1939–41.

Insect	Green Cabbage	Red Cabbage	Cauli-flower	Collards	Broccoli	Brussels Sprouts	Kale	Kohlrabi
Cabbage looper, *Trichoplusia ni* (Hbn.)	x	x	x	x	x	x	x	x
Imported cabbage worm, *Pieris rapae* (L.)	x	x	x	x	x	x	x	x
Diamondback moth, *Plutella maculipennis* (Curt.)	x	x	x	x	x	x	x	x
Cabbage webworm, *Hellula undalis* (F.)	x	x	x	x	x	x	x	x
Cross-striped cabbage worm, *Evergestis rimosalis* (Guen.)	x	x	x	x	x	x	x	x
Granulate cutworm, *Feltia subterranea* (F.)	x	x	x	x	—	x	x	—
Black cutworm, *Agrotis ypsilon* (Rott.)	x	x	x	x	—	x	x	—
Corn earworm, *Heliothis armigera* (Hbn.)	x	x	x	x	x	x	x	x
Cabbage aphid, *Brevicoryne brassicae* (L.)	x	—	—	x	—	—	—	—
Turnip aphid, *Rhopalosiphum pseudobrassicae* (Davis)	x	x	x	x	x	x	x	x
Striped flea beetle, *Phyllotreta vittata discedens* Weise	—	—	x	x	—	—	—	—
Harlequin bug, *Murgantia histrionica* (Hahn)	—	—	—	x	x	—	x	—
Vegetable weevil, *Listroderes obliquus* Klug	x	—	x	x	—	—	x	x
Green peach aphid, *Myzus persicae* (Sulz.)	x	—	—	x	—	x	—	x
Southern green stinkbug, *Nezara viridula* (L.)	x	—	x	x	x	x	x	x
Spotted cucumber beetle, *Diabrotica duodecimpunctata* (F.)	x	—	x	x	x	x	x	x
Banded cucumber beetle, *Diabrotica balteata* Lec.	x	x	x	x	x	x	x	x
Southern cabbage worm, *Pieris protodice* Bdv. & Lec.	x	x	x	x	x	x	x	x
Southern fire ant, *Solenopsis xyloni* McCook	—	—	x	—	—	—	—	—
Greenhouse leaf tier, *Phlyctaenia rubigalis* (Guen.)	x	—	—	x	x	—	—	x

found attacking green cabbage. These additional species are listed below.

Striped flea beetle, *Phyllotreta vittata discedens* Weise
Harlequin bug, *Murgantia histrionica* (Hahn)
The Aphid *Pemphigus populi-transversus* Riley
Fall armyworm, *Laphygma frugiperda* (A. & S.)
Garden webworm, *Loxostege similalis* (Guen.)
Yellow-striped armyworm, *Prodenia ornithogalli* Guen.
Onion thrips, *Thrips tabaci* Lind.
Southern fire ant, *Solenopsis xyloni* McCook
Salt-marsh caterpillar, *Estigmene acrea* (Drury)
Field cricket, *Acheta assimilis* F.
Cotton aphid, *Aphis gossypii* Glov.
Pale-striped flea beetle, *Systena blanda* Melsh.
White-lined sphinx, *Celerio lineata* (F.)
The arctiid *Ecpantheria deflorata* (F.)

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Detrimental Effect of Rotenone on *Rodolia cardinalis*

PAUL DEBACH, *University of California Citrus Experiment Station, Riverside*

The vedalia *Rodolia cardinalis*, has for years been acknowledged as one of the classical examples of a successful entomophagous insect. Its host, the cottony-cushion scale, *Icerya purchasi*, is generally kept at a very low population density by vedalia in California, although the scale is rather uniformly distributed throughout the citrus areas. Occasionally, however, heavy infestations of cottony-cushion scale develop on citrus concurrent with the absence, for one reason or another, of vedalia. This condition was noted, during the 1920's, to coincide with arsenical spray applications to citrus. DDT appeared to be causing the same condition during 1946. This led to the initiation of studies concerning the effect of insecticides on the cottony-cushion scale-vedalia complex.

Severe infestations of cottony cushion scale developed in a considerable number of citrus groves during 1946 following DDT applications, especially in Tulare County. The distribution of cottony-cushion scale in certain experimental groves made it appear, however, as if materials other than DDT might possibly be producing similar effects. One grove, for instance, which the writer followed in detail during 1946 showed a build-up and a fairly heavy infestation of cottony-cushion scale by August 1946. Vedalia was just getting started at this time. This grove had no DDT but received an application of an oil spray containing rotenone in April.

With these field observations as a background, as well as Haug & Peterson's (1938) laboratory work showing derris to be toxic to *Hippodamia*, preliminary toxicity tests were run to obtain further data on the effect of rotenone against vedalia. Leaves were obtained from an experimental plot in a navel orange grove in Tulare County carrying a spray deposit of cube (0.95 lbs. cube root (5 per cent rotenone) in 1.5 gallons kerosene plus 0.3 lbs. blood spreader per 100 gallons water). This spray was applied August 7, 1946, and the leaves were picked August 21, a weathering period of 14 days with daily temperatures ranging to 90°F. or above. Vedalia pupae were obtained from the field and the emerged adults of comparable ages tested for contact toxicity by confining them in petri dishes with the sprayed leaves. Checks using untreated leaves were run. Food and water were supplied. The results are given in Table 1.

Table 1.—Total per cent mortality over a period of days of *Rodolia cardinalis* adults confined in petri dishes with cube sprayed leaves and with untreated leaves.

DAYS	CUBE (2 REPLICATES— 25 ADULTS)	CHECK (3 REPLICATES— 35 ADULTS)
	Per cent	*Per cent*
1	12	3
2	48	11
3	76	23
4	100	26

Although mortality from rotenone was not unexpected, the above results obtained from leaves weathered during two weeks of high summer temperature were indeed striking, and indicate the possibility that because of adverse effects on vedalia populations, rotenone as well as DDT (unpublished data) may be potentially dangerous when applied to citrus trees bearing incipient infestations of cottony-cushion scale, especially when two or more applications are made during the season or when used before or after DDT applications. Further studies are planned on the timing of applications, types of formulations and other factors in order to reduce to a minimum the possible harmful effects of rotenone, DDT, and perhaps other materials, on vedalia populations.—10-12-46.

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Spittle Insect Damage to Alfalfa and Red Clover

E. H. FISHER and T. C. ALLEN, *University of Wisconsin, Madison*[1]

Infestations of spittle insects (Cercopidae) were observed in abnormally large numbers on alfalfa and red clover during 1944 and 1945 in Wisconsin. Carrots, peas, strawberries, and some other crops were also infested with both nymphs and adults. In certain fields of alfalfa and clover in Sheboygan County, one semicircular sweep of a 14-inch insect net caught about 100 adult spittle insects. Insect damage was apparent even in fields with heavy plant stands.

Careful observations of such infested fields of both alfalfa and clover revealed dwarfed, rosetted, blossom-blasted, and necrotic conditions of many plants (Fig. 1). The injured areas of the plants harbored a

[1] Approved by the Director of the Wisconsin Agricultural Experiment Station.

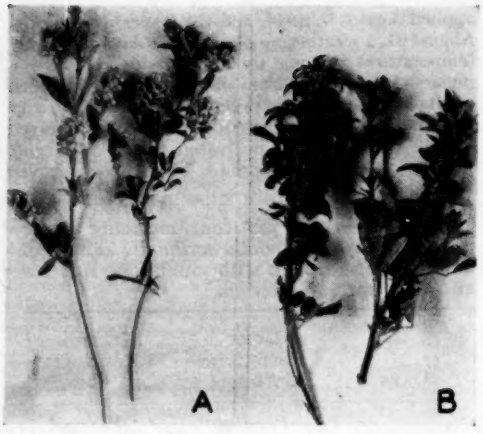

FIG. 1.—A. Undamaged alfalfa. B. Damage to alfalfa due to feeding by spittle insects.

number of feeding spittle insects, particularly the adults that might be responsible for part or all of the damage.

In an effort to reproduce these symptoms, adult spittle insects were confined upon healthy alfalfa and clover plants. Cylindrical screen cages were placed over healthy-appearing second-growth alfalfa and red clover in a field which was developing blossom buds. Each cage enclosed either alfalfa stems or clover stems. Representative samples of adult spittle insects were collected from the field, and placed in half of the cages enclosing each alfalfa and clover, the remaining cages contained no insects. The insects employed were identified[2] as *Philaenus leucophthalmus* (L.), the varieties being of the following percentages: *P. l. pallidus*, 60; *P. l. spumarius*, 21; *P. l. fabricii*, 17; *Pl. l. lateralis*, 2.

Results after one month of insect feeding showed damage like that observed on the first growth alfalfa and clover. Dwarfing was expressed by exceedingly shortened internodes. This damage appeared distinct from the yellows induced by the potato leafhopper since the foliage remained quite green, and rosetting was common.

In Wisconsin considerable losses of such crops may occur in seasons of insect abundance. It is evident that further studies are needed to determine the relative damage caused by the several varieties of spittle insects which do this damage.—9-5-46.

[2] Kathleen C. Doering; Department of Entomology, University of Kansas; Lawrence.

Effect of Oil Sprays on Resistance of California Red Scale to HCN Fumigation

HAROLD R. YUST, H. D. NELSON and ROBERT A. FULTON, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Fumigation with hydrocyanic acid, spraying with oil, and combinations of these two treatments are generally used in the control of California red scale, *Aonidiella aurantii* (Mask.), on citrus trees. It is the expressed opinion of some growers that the use of an oil spray in regularly fumigated groves renders the scales easier to kill in subsequent fumigations with hydrocyanic acid. Lindgren and Dickson (1942) have shown that red scales which survive an oil spray are not more susceptible to fumigation than unsprayed scales. Cressman (1941) reported that strains of scale resistant and nonresistant to hydrocyanic acid do not differ in susceptibility to oil spray. In a further study of the oil spray-fumigation relationship laboratory tests were made in 1943 to determine whether the application of oil to red scales increased the susceptibility of their progeny to hydrocyanic acid.

A resistant strain of California red scale with a history of 14 repeated laboratory fumigations with hydrocyanic acid (Yust *et al.* 1943) was used in the tests. One group of scales of this strain (group A) was maintained without further treatment, and another group from the same source (group B) was oil-sprayed. The scales in group B were propagated from the offspring of the survivors. The oil spray was applied to three successive generations when the female scales were mature but before reproduction commenced. In the first and second sprays 1 per cent of light medium oil was applied and in the third 0.75 per cent. The mortality from each spray was over 50 per cent.

Offspring from the survivors of the first and third treatments were reared on lemon fruits simultaneously with scales of the corresponding generation of group A and fumigated with hydrocyanic acid when the females were in the second-molt and mature stages of development. (A very high mortality resulted from the second spray application, and sufficient offspring were not available for a test following this treatment.) The scales for the fumigation tests were reared in the laboratory. Those following the first oil spray were reared at fluctuating temperatures, and those following the third oil spray were reared at a constant temperature of 77° F. The scales were exposed to a constant concentration of hydrocyanic acid for 40 minutes in the laboratory fumigation chamber. The scales in the second molt were fumigated with a concentration of 1.39 mg. per liter after the first oil spray and 1.57 mg. per liter after the third oil spray. The mature females were fumigated with a concentration of 0.4 mg. per liter in both cases. The results are presented in table 1.

Table 1.—Effect of repeated oil sprays on the resistance to hydrocyanic acid of California red scale.

Oil Sprays	Mortality, Per Cent			
	Second molt		Mature female	
	Group A	Group B	Group A	Group B
First	28.6	27.8	48.2	44.2
Third	48.1	46.4	39.4	30.3

If the oil sprays decreased resistance to hydrocyanic acid, the kills of group B, whose progenitors were oil-sprayed, would be higher than those of group A, but insofar as there was any difference in the kills it was in the reverse order. The beneficial results attributed to substituting spray treatments in a fumigation program are probably due to the generally recognized fact that oil sprays and fumigations are complementary treatments (Woglum & La Follette 1926); that is, with oil sprays the best kill is obtained on the outer part of the tree and on the fruit, whereas with hydrocyanic acid fumigation the best kill is on the inside, especially on the wood.—11-9-46.

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Establishment of an Interdepartmental Committee on Pest Control

In response to an invitation from the Secretary of Agriculture, the Departments of Interior, War, Navy, and the Federal Security Agency joined in the establishment of an Interdepartmental Committee on Pest Control. This Committee was created in response to correspondence begun in October 1945, and its members were designated by the heads of these units of the Federal Government. The purpose of the Committee is to provide a means for the exchange of information and free discussion on matters relating to control of insect pests, diseases, rodents, weeds, etc., and to consider problems of mutual interest, such as:

(a) The field of research, including cooperative planning where desired and free interchange of information on results;
(b) collaboration in preparing and issuing information to the public on matters which cover the general field of chemicals used in pest control;
(c) collaboration and coordination in planning and executing control programs where there is a joint interest; and
(d) unification of policies on the use of such chemicals when they are applied for controlling pests over large areas.

It is not intended that the Interdepartmental Committee direct, duplicate, or conflict with the activities of other groups concerned in insect and pest control that are carried on by Federal agencies and their cooperators. It is proposed that it augment their activities by providing a means of crystallizing and pointing up work of the several units of the government interested in and responsible for work in research, education, and control of pests. It is not expected or intended that responsibilities of the various units of the government will be assumed by the Committee. It will, instead, aid in preventing undesirable duplication and provide a means of carrying out the activities of the several Federal agencies to the best interest of social progress through joint consideration of matters of mutual interest.

By design the Committee is to be limited in size, being composed of two or three representatives from each governmental unit. It is proposed, however, that as occasion and subject matter demand members will bring other representatives from their agencies to discuss matters in special fields that may be considered by the Committee, and that the Committee may secure the advice, counsel, and assistance of specialists employed by any of the represented Departments.

Unless otherwise called for specific purposes meetings are held bi-monthly in the South Agriculture Building, Washington, D. C. Two meetings have been held since the organizational meeting in March. The main topic at the second meeting was a review and consideration of research and action programs pertaining to insects which attack and annoy man or are vectors of human diseases. The third meeting was devoted largely to consideration of problems concerned with the carriage of insects and insect pests by airplanes, including review of research aimed to reduce the risk, and control and quarantine activities designed to prevent the introduction, spread, and establishment of insect pests by these means.

The members of the Committee are:

Agriculture
Bureau of Entomology and Plant Quarantine
Mr. S. A. Rohwer, Assistant Chief
Chairman of Committee
Insecticide Division, Livestock Branch
Production and Marketing Administration
Dr. W. G. Reed, Chief

Federal Security Agency
Industrial Hygiene Research Laboratory
National Institute of Health
U. S. Public Health Service
Dr. Paul A. Neal, Chief
Secretary of Committee
Carter Memorial Laboratory
U. S. Public Health Service
Savannah, Georgia
Dr. S. W. Simmons, In Charge
Food Division, Food and Drug Administration
Dr. W. B. White, Chief

Interior
Division of Fishery Biology, Fish and Wildlife Service
Mr. Elmer Higgins, Chief
Division of Wildlife Research, Fish and Wildlife Service
Dr. Clarence Cottam, Chief (Chicago)
Dr. Frederick C. Lincoln, Asst. to Chief, Alternate (Washington)

Navy
Preventive Medicine Division, Bureau of Medicine and Surgery
Captain Otto L. Burton (MC), USN, Chief
Insect and Pest Control Section, Preventive Medicine Division,
Bureau of Medicine and Surgery
Commander J. D. DeCoursey, USNR
Bureau of Ships
Mr. Harry Fleisher

War
Office of the Surgeon General
Lt. Col. J. W. Regan
Office of the Quartermaster General
Mr. William M. Lee
Office of Chief of Engineers
Mr. W. D. Reed

At the first meeting of the Committee on March 13, 1946, Mr. S. A. Rohwer of the Bureau of Entomology and Plant Quarantine was elected Chairman, and Dr. Paul A. Neal of the U. S. Public Health Service was appointed Secretary.

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Reflections on the Richmond Meeting

Now while the Richmond meeting is fresh in the minds of those who attended seems an opportune time to record some thoughts and observations on the meeting. Comments on all phases of the program were in general very favorable. The last-minute transfer from Pittsburgh to Richmond presented unprecedented problems to the program and local arrangement committees, but both performed excellently. The suggestions offered at this time are not in criticism or defense of anyone but merely for the consideration of all members, especially those who will plan for the 1947 meeting.

THE FINAL BUSINESS MEETING of the Association was entirely too long and unavoidably delayed the program which followed it. To prevent such occurrences in the future the following might be considered:

The preliminary business meeting should transact most of the important business of the Association and be scheduled for sufficient time to receive reports of all committees except Resolutions and Nominations. The Executive Committee could present all business referred to it with more opportunities for discussion from the floor than the present arrangement permits; in other words, an open meeting of the Executive Committee. Any other actions taken by the Executive Committee during the meeting could be reported briefly at the final business session. In preparation for this preliminary meeting the Executive Committee could hold a full day's session the day before the regular program begins. Certainly members of the Executive Committee who plan to attend a meeting would not object to coming a day earlier, but if such a session is to achieve its objectives the sponsors of petitions and chairmen of committees recommending action by the Executive Committee should have their petitions and reports in the hands of the secretary prior to the session. After the regular meeting begins, with a day-and-night program, the Executive Committee does not have time to study proposals thoroughly.

IN PAPER READING SESSIONS time limits should be announced in the program if possible and be strictly adhered to. Very few research reports require more than 10 minutes for presentation if properly summarized—and the summary is usually all that should be read, leaving the details for the printed paper in the JOURNAL. If the time allotted each paper is not printed in the program, the chairman of each group should determine the average time available for the papers scheduled and not allow any speaker to monopolize the time of others.

For several years *the presidential address* has been scheduled as the first item on the first day's program, or no later than noon on the opening day. Many members are arriving all during the opening day and could hardly be expected to leave home a day earlier just to arrive in time for this address. Only those who have prepared such an address know the agony of mind one suffers in trying to select a subject that will be of interest to the Association, and then the hours and days spent in gathering data and in preparation of the paper. It would seem that this effort might be rewarded by scheduling the address during the second day, following it immediately with the preliminary business meeting, which should also be attended as fully as possible. Paper reading sessions and sectional meetings on the first day might not be as well attended as at present, but if detailed programs are published sufficiently in advance those especially interested in certain papers or sections would arrange to be present.

THE TREND TO INDUSTRY. A larger proportion of the attendance at Richmond

represented industrial organizations than at any previous meeting. Scores of entomologists who were on federal or state staffs a year ago are now on industrial payrolls. In most cases their places cannot be filled with men of comparable training or experience. They are simply not available. In nearly all institutions very attractive graduate assistantships or fellowships are going begging, and where they are filled the holders are being snapped up by industry as fast as they secure degrees, especially if the student has been on an industrial fellowship. I am not protesting against this situation as it is a commendable development which should result in greater net progress in economic entomology, for the workers in practically all cases now have more funds and better facilities for research than the state and federal agencies provided for them. However, the dearth of entomological graduates during the war period, followed by this loss of a large number of trained workers will seriously handicap governmentally-supported research for the next few years. It will, therefore, not be surprising if much of the progress in insecticides in the immediate future has its origin in industrial laboratories.

Competition among new materials will be very keen in many fields, and this places on industrial entomologists the responsibility for adhering to the highest ethical standards in making claims for their products. The state or federal worker, operating with a reduced staff, will, in all probability, not be able to evaluate on as extensive scale as he desires, all of the promising products appearing on the shelves of dealers. Extension entomologists and others responsible for recommendations in the states may have to depend in many cases on the claims of the manufacturer, and if these claims are not based on careful and extensive tests all entomological work will suffer. The addition of these professional entomologists to industrial staffs should make all the more dependable the claims and recommendations of such firms.

CLAY LYLE

OBITUARY

Alice W. Averill

Alice W. Averill, for 38 years serving the Maine Agricultural Experiment Station as Technical Assistant in Entomology, died the 21st of November, 1946.

During those years Miss Averill prepared about 40,000 slides of aphids. These were studied not only by those entomologists of the Maine Station working with aphids but also by guests from other states and Canada who came to examine slides of species concerning which they desired information. Many of these slides have been borrowed by entomologists in Europe, Asia, Africa, Australia, and South America. So Miss Averill's efforts in this regard have had world-wide significance in aiding the study of these insects. On the label of each slide was recorded the name of the plant from which the aphids were taken, locality and date of collection. A manuscript catalogue of all these slides was kept under the headings of each plant family concerned.

Miss Averill also kept up to date lists of food plants recorded in all accessible aphid papers. Acknowledgment is made of her assistance in the routine work in the preparation of *Food-Plant Catalogue of the Aphids of the World.* (Me. Agr. Exp. Sta. Bul. 393, 1938.) In 1945 the Experiment Station published Miss Averill's *Index to Genera and Species of Food Plants* included in this *Catalogue.* (Bul. 393-S.)

During all the years since 1908 when Miss Averill began her work at the Experiment Station, she has been appreciated as a pleasant and faithful member of the staff. Her whimsical sense of fun remained with her in sickness as in health and she was joking with her doctor a few minutes before her death.

The daughter of William S. and Annie Averill, she was born in Orono and lived here all her life. She was a member of the Orono Rebekah lodge, attended the Methodist church, and was secretary of the Orono chapter of the Order of the Eastern Star for many years. Surviving are one brother, Fred Averill, of Brewer, Maine, and several cousins.

EDITH M. PATCH

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